1.0
BACKGROUND AND OBJECTIVE

1.1 INTRODUCTION

The Department of Natural Resources (department) oversees response, characterization, risk assessment, and risk management under a variety of authorities at over two thousand contaminated sites in Missouri. Many more sites are in an early stage of investigation or as yet unknown to the department. The impetus and philosophy behind **Missouri Risk-Based Corrective Action** (MRBCA) is to provide a framework for cleanup decisions that facilitates the constructive use of contaminated sites by protecting human health and the environment in the context of current and future site use. This framework can streamline the process of site cleanup and closure and focus finite resources on sites with the highest current or potential risks to human health and the environment.

Risk management and associated activities at contaminated sites cross departmental programs and divisions. Within the Hazardous Waste Program, a number of state and federal cleanup authorities work together, such as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), federal and state-equivalent Resource Conservation and Recovery Act (RCRA), Brownfields/Voluntary Cleanup Program (B/VCP), and Petroleum Storage Tanks (PST). The Water Protection, Land Reclamation, Air Pollution, and Environmental Services Programs and the Geologic Survey and Resource Assessment Division are often involved in risk management decisions.

In addition, the Missouri Department of Health and Senior Services (DHSS) is responsible for protecting and promoting public health. In this capacity, it may conduct or review risk assessments, provide review and comment on site characterization and remediation plans, and advise the department on risk management decisions.

While the primary objective of each authority is to protect human health and/or the environment, the specific decision-making framework to achieve this objective can vary among the authorities and programs. Further, the science and available technologies of site characterization, risk assessment and risk management has evolved considerably in recent years. Therefore, this guidance is written to provide a more consistent and predictable regulatory process for responsible parties, development interests, landowners and other entities that are involved in the evaluation and management of contaminated sites. (In this document, these entities and their designees are referred to collectively and generically as the "remediating party").

Because of the tremendous interest in the MRBCA process, the department developed this guidance in association with a formal stakeholder group, called the Risk-Based Remediation Rule Workgroup (Workgroup). This effort led to the development of a department-wide, risk-based program. This same Workgroup also worked together to produce the ***Missouri Risk-Based Corrective Action (MRBCA) Process for Petroleum Storage Tanks*** (first published in February, 2004), which applies specifically to petroleum storage tanks.

This department-wide program should provide (i) a scientifically defensible and consistent framework to make decisions related to site characterization, risk assessment and risk management and (ii) a predictable regulatory process for property owners and developers. An additional benefit may be a reduction in the overall costs of these activities. Although applicable laws do not allow cost considerations to compromise human health, public welfare or the environment, the department recognizes the need to promote cost-effective site characterization and cleanup activities.

This technical guidance describes the key elements and methodologies of the MRBCA process. It is consistent with the risk-based corrective action standard developed by the American Society for Testing and Materials (ASTM E1739-95). However, it has been modified to account for the large variety of sites and contaminants for which it is applicable and in response to input from the Workgroup.

1.2 APPLICABILITY

This guidance applies to contaminated or potentially contaminated sites. It provides a methodology to conduct site-specific characterization; calculate risk-based levels protective of human health, public welfare and the environment; and implement appropriate risk management activities including any long-term stewardship requirements. In short, the guidance should orchestrate the restoration of contaminated sites (and sites perceived to be contaminated) for safe reuse. Although the department does not intend to re-open sites previously closed under other programs, this guidance will be applicable to new releases discovered at previously closed sites, newly discovered sites, on-going cleanups, and site reviews where a different use is being contemplated than planned for at the time of closure.

The MRBCA process is applicable to numerous authorities under which the department oversees site characterization and cleanup activities. A brief overview of the department's programs and authorities related to remediation is discussed in Section 3.0. However, the MRBCA process does not in any way supercede or change applicable federal statutes and regulations. It does not supercede the requirement that state programs authorized by the USEPA (for example, RCRA) that are operating in lieu of the federal program be at least as stringent as the federal program. It does not change the federally mandated, program-specific administrative, technical and notification requirements on either a remediating party or regulators. For petroleum storage tanks, a parallel risk-based process is described in the most recent edition of the **Missouri Risk-Based Correction Action (MRBCA) for Petroleum Storage Tanks.**

A review of the department's regulatory authorities has indicated that the department has the authority to use risk-based decision-making at contaminated sites, and in fact the department has applied a risk-based process to many sites. MRBCA may be used in hazardous waste enforcement cases where the department and a remediating party enter into a binding or enforceable agreement (such as a permit or order) that states how and when MRBCA applies to a specific site. MRBCA may be also used in instances where the department and a remediating party enter into a voluntary agreement such as an expedited corrective action letter of agreement. This guidance is intended to complement the MRBCA rule when it is in effect. If there is any conflict between the guidance and the rule, then the rule prevails.

When used, this approach is applicable to all media and the entire contaminated site. Neither the remediating party nor the regulators can pick or choose portions of the media or sites to which this process will apply.

This technical guidance has been written for environmental professionals who have experience in site characterization, risk assessment and risk management. Because the development of risk-based target levels is an integral part of the overall process of risk management and has not been previously described in any of Missouri's guidance documents, the calculation of risk-based target levels is described at length in this guidance. However, it is not intended to be a guide to every aspect of the practice of site characterization, risk assessment or risk management. Prior experience or training is necessary for an individual to correctly implement the MRBCA process and, by that, ensure efficient and safe site management. The department also recognizes that every site is unique and that no single guidance document can cover all the scientifically available methods for characterizing and remediating sites.

The department expects that the MRBCA process and its associated policies, procedures and assumptions will evolve as environmental professionals (regulators, consultants, responsible parties, and others) and the public gain familiarity with the process. Thus the department anticipates revising and updating this document from time to time in accordance with Appendix A, Updates and Revision to the MRBCA Process.

1.3 LONG-TERM STEWARDSHIP

As part of the adoption of a risk-based program to manage contaminated sites, the state must guarantee that knowledge of and adherence to the department-approved, safe uses of that site are ensured for as long as the site has any residual contamination above unrestricted use levels. Therefore, the MRBCA process requires that, to fully protect human health, public welfare and the environment, an appropriate system of controls, institutions and information - referred to as "Long-Term Stewardship" - will be an integral part of Risk Management Plans.

2.1 INTRODUCTION

The **Missouri Risk-Based Corrective Action** (MRBCA) process begins after a contaminated site has been identified. The process includes all subsequent department-approved activities needed to ensure that the site does not pose an unacceptable risk to human health, public welfare or the environment, including any necessary **long-term stewardship** (LTS) requirements if residual contamination remains on site. The MRBCA process consists of the following three steps:

- **Site characterization** and delineation of impacts to soil, groundwater, surface water, sediments, and soil vapor to the extent necessary based upon site-specific considerations. Site characterization information is used to develop a **conceptual site model**, which will lead to the development of an **exposure model**;
- **Risk assessment** conducted at the Tier 1, Tier 2, or Tier 3 level. Risk assessment culminates in the estimation of risk and, as appropriate, the development of **risk-based target levels** for the environmental media impacted by **chemicals of concern** (COCs) at the site. The assessment of risk involves determining the e**xposure pathway**, which is the course a chemical takes from a source of contamination to the **receptor**. A receptor is an organism that receives, may receive, or has received exposure to a COC as a result of a release. (These terms and others are defined in Appendix L and discussed more completely throughout the guidance.) The results of the risk assessment are used to determine and implement the nature and scope of site-specific risk management activities; and
- **Risk management** activities that protect human health, public welfare and the environment under current and future uses on and near the site by ensuring that any unacceptable risks identified by the risk assessment are managed. Risk management activities include any necessary remediation activities and any LTS activities needed to guarantee that, for as long as residual contamination on site remains above unrestricted use levels, there will be knowledge of and adherence to the assumptions included in the risk calculation.

Figure 2-1 illustrates these steps. Although the process is fundamentally technical and relies on a variety of scientific disciplines (such as geology, hydrology, engineering, chemistry, toxicology and land use planning), it also uses assumptions and policy choices that must be consistent with state and federal laws and regulations. This section is an overview of the process; subsequent sections provide more detail on each step.

2.2 RISK-BASED CORRECTIVE ACTION PROCESS

The decision-making process for a site where contamination is suspected or discovered is illustrated in Figure 2-2 and discussed below:

2.2.1 Site Discovery

The department may learn about a contaminated site under a variety of circumstances. Some of these are:

- Citizen complaints,
- Investigations conducted as a part of real estate transactions,
- Investigations conducted in anticipation of land development,
- Environmental impacts observed in surface water bodies,
- Site inventories developed by the department, and
- Notification of accidents and spills.

Various federal statutes and regulations administered by the department (such as RCRA and CERCLA) impose notification and public participation requirements on responsible parties. This document does not change any of the responsibilities or obligations to notify the appropriate state and federal agencies in accordance with specific authorities.

The process of site discovery and notification is further discussed in Section 3.0.

2.2.2 Determination and Abatement of Imminent Threat(s)

Upon discovery that a site may contain potential contamination, all available information must be carefully evaluated to determine if the site poses any imminent threat to human health, safety or the environment. The following need to be evaluated:

- Actual or potential threats to drinking water supplies (private or public groundwater or surface water) and sensitive ecosystems,
- Threat of fire and explosion,
- Actual or potential threat of release to a surface water body,
- High levels of chemicals in surface soils that can migrate in a vapor, dissolved or non-aqueous phase,
- Actual or potential exposure to nearby human populations, animals or the food chain, and
- Weather conditions that may cause hazardous contaminants to be released or migrate.

If any imminent threats are discovered, the department must be informed immediately (Sections 260.500-.550, RSMo and the accompanying regulations at 10 CSR 24-1.010 through 3.010).

If the department or the remediating party identifies an imminent threat, the remediating party must immediately begin abatement actions under the direction of the department. Examples of abatement measures include:

- Provision of an alternate water supply if drinking water wells are impacted,
- Permanent or temporary evacuation of residents or commercial workers if either are exposed to immediate risk,
- Installation of booms on surface water bodies to contain contaminants creating a sheen,
- Ventilation of confined spaces that contain vapors at concentrations that may cause an explosion or other imminent risk,

- Installation of fences or warning signs,
- Drainage control,
- Stabilization, or
- Capping of highly contaminated surface soil.

Upon completion of abatement actions, the remediating party must submit a report to the department that documents the activities and confirms that all imminent threats have been abated. This report must also include recommendations for any additional work necessary for the continued protection of human health, public welfare and the environment.

Determination and abatement of imminent threat(s) are further discussed in Section 4.0.

2.2.3 Initial Characterization and Comparison with Default Target Levels

After completion of any emergency response actions or time-critical removal actions, or upon site discovery if no emergency action is necessary, the remediating party must perform an ***Initial Characterization***. The objective is to identify with certainty the maximum concentrations of the COCs in each impacted environmental media and compare these concentrations with **default target levels** (DTLs)and Water Quality Criteria (10 CSR 7.031). Default target levels are the levels necessary to quantify and protect receptors from all complete exposure pathways for unrestricted use

Characterization includes collection of media-specific data for all media of concern to characterize the source(s) and concentrations of site related chemicals. This step focuses fieldwork (drilling of temporary wells, collection of soil, soil vapor, or groundwater samples, etc.) to identify the maximum concentrations of COCs in the affected media. The level of effort (number of sampling points, etc.) necessary for an adequate initial characterization is dependent upon site-specific conditions.

Impacts should be delineated to the higher of DTLs or other levels necessary to protect the receptors from complete routes of exposure. For example, in a non-residential site with appropriate activity and use limitations, the delineation criteria may be non-residential risk-based target levels. Or, if an ecological threat exists, delineation criteria must be the level protective of the ecological species.

However, for sites that may require additional characterization or remediation, it may be more cost effective at this point to delineate the nature and extent of impacts rather than only identifying the highest concentrations. Proposed additional characterization should be included in the site characterization work plan.

The initial characterization should result in identification of the impacted environmental media at a site, the point or points of release, the COCs, and the location and maximum concentrations of the COCs. If, during the course of investigation, the analytical detection limit for any COCs is higher than the corresponding Default Target Level, Section 5.3 provides further guidance.

The maximum COC concentrations are then compared with the DTLs. If discharge from the site results in potential migration to any water body, then the state Water Quality Criteria must also be considered. If the maximum soil and groundwater concentrations do not exceed the DTLs and if the site poses no ecological risk, the remediating party may petition the department for a Letter of Completion. Under these conditions, the department will issue the Letter of Completion and no activity or use limitations will be required regardless of how the site may be used.

Because the department will make its final decision based on a comparison with acceptable values, the data available for the comparison must accurately represent the maximum media-specific COC concentrations. The term "maximum concentration" refers to the current maximum concentration of a COC. At sites where additional releases or significant migration may have occurred since samples were last collected, new data may be necessary to represent current conditions. Also, concentrations of all COCs may not have reached maximum concentrations in a particular media (usually groundwater) because of travel time. In the latter case, additional monitoring in the future may be necessary to ensure that DTLs will not be exceeded, and therefore further activities would be necessary.

If the maximum soil or groundwater concentrations exceed the DTLs or any applicable water quality criteria, the remediating party may either adopt DTLs and/or water quality criteria as the cleanup levels and develop a risk management plan to achieve those levels, or perform a tiered risk assessment.

Initial characterization and comparison with default target levels is further discussed in Section 5.0.

2.2.4 Development and Validation of Conceptual Site Model

If the maximum concentrations of COCs exceed the DTLs or the DTLs are not selected as the cleanup levels, the remediating party would next develop and validate a **conceptual site model**. A conceptual site model qualitatively and/or quantitatively describes all the relevant site-specific factors that determine the risk to human health and the environment and is the framework for management of a site. The conceptual site model should be documented using narrative descriptions, diagrams and flow charts as appropriate. It may include attachments such as well logs, boring logs, monitoring well construction details, and laboratory reports. The conceptual site model should be revised as new site-specific information is collected and integrated into the understanding of the site.

Key elements of the conceptual site model include:
1. The chemical release scenario, source(s), and COCs,
2. Spatial and temporal distribution of COCs in the various affected media,
3. Current and future land and groundwater use,
4. Description of any known existing or proposed land or water use restrictions,
5. Description of site stratigraphy, determination of vadose zone soil type, hydrogeology, meteorology, and surface water bodies that may potentially be affected

by site COCs,
6. Remedial activities conducted to date, and
7. An exposure model that identifies the receptors, pathways and routes of exposure under current and future land use conditions.

An essential component of the conceptual site model is to determine if the domestic use of groundwater is a complete pathway under current or future conditions. Domestic use of groundwater includes ingestion and inhalation of vapors generated by indoor water use activities such as showering and washing.

The extent of contamination and complete routes of exposure, not the property boundaries, determine the extent of site-specific data collection and analysis.

Data collection activities and data quality objectives must satisfy the development and refinement of the conceptual site model and exposure models.

Data needs to develop a conceptual site model are further discussed in Section 6.0 and Appendix K.

2.2.4 Tier 1 Risk Assessment

If the maximum soil or groundwater concentrations exceed the DTLs, the remediating party may choose to complete a Tier 1 Risk Assessment in lieu of cleanup to the DTLs. Tier 1 provides risk-based target clean-up levels based upon the receptor, land use, soil type and pathway.

For the MRBCA process, the acceptable risk levels are:

Carcinogenic Risk
- The total risk for each chemical, which is the sum of risk for all complete exposure pathways for each chemical, must not exceed 1×10^{-5}.
- The cumulative site-wide risk (sum of risk for all chemicals and all complete exposure pathways) must not exceed 1×10^{-4}.

Non-carcinogenic Risk
- The hazard index for each chemical, which is the sum of hazard quotients for all complete exposure pathways for each chemical (the total risk) must not exceed 1.0.
- The site-wide hazard index, which is the sum of hazard quotients for all chemicals and all complete exposure pathways, must not exceed 1.0.

If the hazard index exceeds 1.0, a qualified toxicologist may calculate the hazard index corresponding to a specific toxicological end point. In this case, the specific hazard indices for each toxicological end point must be less than unity (1.0).

A Tier 1 risk assessment involves:
1. Determination of predominant vadose zone soil type,

2. Determination of site COCs
3. Selection of relevant **Tier 1 risk-based target levels** from lookup tables developed by the department,
4. Determination of whether it is necessary to estimate cumulative site risk to account for multiple chemicals and multiple routes of exposure, and
5. Comparison of relevant risk based target levels with representative concentrations of site COCs.

Tier 1 risk-based target levels will be selected for predominant site-specific vadose zone soil type, each COC, each complete pathway, and each media of concern identified in the exposure model and, if necessary, modified to account for the cumulative site-wide risk. Tier 1 risk-based target levels are based on default input parameters and are presented in Appendix B.

Based on the comparison of representative concentrations and Tier 1 risk-based target levels, the remediating party can make any one of the following three decisions:

1. Request a determination from the department that the residual concentrations are protective of human health, public welfare and the environment,
2. Adopt Tier 1 risk-based target levels as the cleanup levels and prepare and submit a Risk Management Plan to manage the risk associated with these levels, or
3. Perform a Tier 2 risk assessment.

Upon completion of the Tier 1 risk assessment, the remediating party must provide a Tier 1 Risk Assessment Report to the department. If the remediating party chooses to immediately perform a Tier 2 risk assessment, the Tier 1 and Tier 2 assessments may be combined into a single report that is submitted to the department at the conclusion of the Tier 2 assessment.

If the remediating party concludes that the concentration of COCs are protective of human health, public welfare and the environment and requests a **Letter of Completion** from the department, the request must be supplemented with a long term stewardship plan unless residual concentrations meet unrestricted use levels.

The Tier 1 risk assessment is further discussed in Section 8.0.

2.2.6 Tier 2 Risk Assessment

Tier 2 risk assessments allow for the use of site-specific fate and transport parameters to calculate site-specific risk-based target levels.

In preparation for a Tier 2 risk assessment, additional data should be collected and the exposure model should be revised as needed. Tier 2 **site-specific target levels** are calculated values based on site-specific data such as the nature and extent of contamination and physical characteristics of the site.

After the Tier 2 site-specific target levels have been calculated, they are compared with representative COC concentrations at the site. Depending on the comparison, the remediating party can make any one of the following three decisions:

1. Request a determination from the department that the residual concentrations are protective of human health, public welfare and the environment,
2. Adopt calculated Tier 2 site specific target levels as cleanup levels and develop a risk management plan to manage the risk associated with these levels, or
3. Develop a work plan for a Tier 3 risk assessment.

Upon completion of the Tier 2 risk assessment, the remediating party must provide a Tier 2 Risk Assessment Report to the department.

The Tier 2 risk assessment is further discussed in Section 9.0.

2.2.7 Tier 3 Risk Assessment

A Tier 3 risk assessment allows considerable flexibility in managing risk at a contaminated site. Because of the many options available at Tier 3, the department requires that a work plan be submitted and approved prior to the performance of a Tier 3 risk assessment.

Once Tier 3 site-specific target levels have been developed, they are compared to representative COC concentrations. Depending on the comparison, the remediating party can make either of the following two decisions:

1. Request a determination from the department that the residual concentrations are protective of human health, public welfare and the environment, or
2. Adopt Tier 3 site-specific target levels as cleanup levels and develop and implement a risk management plan.

Upon completion of the Tier 3 risk assessment, the remediating party must provide a Tier 3 Risk Assessment Report to the department.

The Tier 3 risk assessment is further discussed in Section 10.0.

2.2.8 Development and Approval of Risk Management Plan

The objective of all Risk Management Plans is to protect human health, public welfare and the environment under current and future conditions. Typically, a Risk Management Plan will be developed after the department approves media-specific cleanup levels under any of the tiers (DTLs, Tier 1, Tier 2, or Tier 3 levels). In certain cases, the media-specific cleanup levels may be developed as a part of the Risk Management Plan. The Risk Management Plan may include a combination of active and passive remedial options, a description of and schedule for all remedial activities, **activity and use limitations** (AULs), and reports to be submitted.

To the extent needed to protect human health, public welfare and the environment, the plan may include:

1. Remedial technology(ies),

2. Long term stewardship plan, including any proposed AULs and justification for their use,
3. Estimate of the time needed to implement the risk management plan,
4. Monitoring plan to verify the effectiveness of the risk management plan,
5. Manner in which the monitoring data will be evaluated,
6. Monitoring action levels that would require reevaluation of the effectiveness of the risk management plan, and
7. Steps that will be taken if the risk management plan is not effective.

2.2.9 Implementation and Completion of the Risk Management Plan

The Risk Management Plan must then be implemented as written and approved. However, during implementation of the Risk Management Plan, sufficient data must be collected and analyzed to evaluate the performance of the plan and, if needed, to implement modifications. The data and the evaluation must be submitted to the department. If the Risk Management Plan is not progressing as planned and changes are needed, a proposal for modifying the plan must be submitted to the department for approval. Modifications can not be implemented without the approval of the department.

Risk Management Plan activities must continue until the department determines that, based on site-specific data, cleanup goals (DTLs, Tier 1, Tier 2, or Tier 3 levels) have been met, specified AULs are in place, and risks have been appropriately managed. The Risk Management Plan must include a commitment to maintain the AULs for as long as is necessary to ensure protection of human health, public welfare and the environment - that is, as long as residual concentrations exceed unrestricted use levels. The department will issue a **Letter of Completion** that indicates that, based on the MRBCA evaluation and information available to the department at the time, conditions at the site and any controls in place are protective of human health, public welfare and the environment.

In the future, additional information may become available that the site poses an unacceptable risk to human health, public welfare or the environment or that the land use has changed and is no longer compatible with the risk management plan. In either of these cases, the department may rescind its decision and require further action at the site.

Long-term stewardship and the Risk Management Plan are further discussed in Sections 11.0 and 12.0, respectively.

2.2.10 Long Term Stewardship

Long term stewardship (LTS) is the system of controls, institutions and information required to ensure protection of human health, public welfare and the environment at sites where residual contamination has been left in place above unrestricted use levels.

Examples of long-term stewardship tools include:
- Engineering or physical controls,
- Proprietary controls such as covenants where the control is legally a property interest,

- Government controls such as the implementation of zoning and well drilling restrictions,
- Informational devices such as deed notices and databases, and
- Activity and use limitations.

Activity and use limitations (AULs) may be an integral part of long-term stewardship, and, if needed, would be part of the Risk Management Plan. AULs should be designed to ensure that pathways of exposure to COCs, through current or reasonable future uses, are not completed for as long as the COCs pose an unacceptable risk to human health, public welfare or the environment. To achieve this goal, AULs must be durable, reliable, enforceable and consistent with the risk posed by the COCs. Without compromising their protective function, AULs are also intended to facilitate the property transaction, redevelopment and beneficial reuse of brownfields and other contaminated properties.

In the Missouri risk-based process, the following general principles apply.

- Activity and use limitations are required for any site where COC concentrations exceed levels that are safe for unrestricted use.
- The future uses of sites may be limited, permanently or temporarily, by restrictive covenants or other means, and risk management plans may be developed based on limited future site uses.
- The use of engineering or physical controls in a Risk Management Plan will be accompanied by legal controls to ensure the controls are observed and maintained.
- Activity and use limitations can be removed if COC concentrations no longer exceed unrestricted use levels.

2.3 RISK-BASED TARGET LEVELS WITHIN THE MRBCA PROCESS

Under the MRBCA process, any of the following four target levels may be accepted as the cleanup levels.

1. **DTLs** are the most conservative chemical and medium-specific concentrations that allow unrestricted use of the property. For each COC and each medium, the DTL is the lowest of the Tier 1 risk-based target levels. Because DTLs are the most conservative values, their application does not require evaluation of site-specific exposure pathways, the development of a conceptual site model, any activity and use limitations, or the determination of whether groundwater is used or is likely to be used for domestic consumption. Issues related to cumulative site-wide risk should be discussed with the department's project manager.

2. **Tier 1 risk-based target levels** are generic values developed by the department using conservative default parameters that depend on the predominant vadose zone soil type, receptor, media, pathway, route of exposure and domestic use or likely use of impacted or threatened groundwater. The Tier 1 generic target levels presented in Appendix B should be evaluated to ensure that cumulative site-wide risk does not exceed the acceptable risk level of 1×10^{-4} or a Hazard Index of 1. Use of Tier 1 risk-based target levels may require AULs.

3. **Tier 2 site-specific target levels** are values that are calculated using site-specific data and this technical guidance. Tier 2 site-specific target levels differ from Tier 1 risk-based target levels in that the Tier 2 site-specific target levels are based on site-specific fate and transport parameter values, whereas the Tier 1 risk-based target levels use default fate and transport parameters. For each receptor, additivity of risk (for each chemical and each route of exposure) and cumulative site-wide risk (for all chemicals and all routes of exposure) must be considered. Typically, but not always, Tier 2 site-specific target levels will be higher than Tier 1 risk-based target levels. As with Tier 1 risk-based target levels, AULs may be required.

4. **Tier 3 site-specific target levels** are also values that are calculated using data collected at the site and the guidelines in this document. However, compared with Tier 2 site-specific target levels, Tier 3 site-specific target levels may be based on the application of fate and transport models other than those used to calculate the Tier 1 risk-based target levels and Tier 2 site-specific target levels. Additivity of risk and cumulative site-wide risk must be considered. The application of Tier 3 site-specific target levels may also require the use of AULs.

Table 2-1 compares the different tiers within the MRBCA framework. However, as an analysis moves from DTLs through the tiers, if the target cleanup levels become lower, the remediating party does not have the option of using higher levels from the previous tier. The higher tier target levels are based on site-specific information and hence are expected to be a more accurate representation of potential risks at the site. For large sites, different sections of the site may be managed using different risk-based target levels and different AULs.

2.4 RATIONALE AND CHARACTERISTICS OF TIERED APPROACH

Despite the differences between the three tiers, there is one very significant similarity: *each tier will result in cleanup target levels that provide an acceptable level of protection to human health, public welfare and the environment.* Thus the process provides considerable flexibility and a variety of options to manage site-specific risks. The remediating party working with the department can thus select the optimal strategy.

As a site moves through the tiered process, the following can be anticipated:

- Higher tiers will require the collection of more site-specific data, which will increase data collection, data analysis, and labor costs.
- In general, the calculated Tier 2 site-specific target levels will be higher than the Tier 1 risk-based target levels and Tier 3 site-specific target levels will be higher than Tier 2 risk-based target levels. This is because lower tier target levels are more conservative than higher tier target levels. Thus, the cost of risk management activities at higher tiers should generally be lower.
- The need for, and the extent of, regulatory oversight and review will increase as the site moves from Tier 1 to Tier 2 and then Tier 3.
- The level of uncertainty and conservatism will decrease from Tier 1 through Tier 3 due to the availability of more site-specific data.

2.5 DOCUMENTATION OF THE MRBCA PROCESS

To make decisions that protect human health, public welfare and the environment, the MRBCA process requires the collection and analysis of a considerable amount of data. In addition, a variety of stakeholders – for example, state agencies, landowners, developers, lending agencies, and local governments – may be interested in the outcome of the MRBCA process. Therefore, the process by which data is collected and analyzed and by which decisions are made must be as transparent as possible through adequate and clear documentation.

The method and format by which the remediating party reports data from the MRBCA process also must be consistent across the state and unambiguous so that stakeholders can readily understand the:

- Data collected to quantify and analyze the problem,
- Nature and extent of the problem at a site,
- Process used to develop a plan of action to address the problem,
- Sequence of actions taken to address the problem,
- Results of the actions taken, and
- Conclusion that actions taken are protective of human health, public welfare and the environment under current and future conditions.

For reference, reports that may be required in the MRBCA process, but not necessarily so, are listed below. Note that specific authorities, such as RCRA or CERCLA, use different reporting titles and formats.

- Determination and Abatement of Imminent Threats,
- Initial Characterization and Data Collection Work Plan,
- Initial Characterization Report,
- Site Characterization and Data Collection Work Plan,
- Tiered Risk Assessment Report (Tier 1, 2, or both),
- Tier 3 Work Plan,
- Tier 3 Risk Assessment Report,
- Risk Management Plan, or
- Completion of Risk Management Plan.

Table 2-1
Comparison of Risk Assessment Options

Factors	DTL	Tier 1	Tier 2	Tier 3
Exposure Factors1	Default	Default	Default	Site-specific
Toxicity Factors1	Default	Default	Default	Most current
Physical and Chemical Properties1	Default	Default	Default	Most current
Fate and Transport Parameters1	Default	Default	Site-specific	Site-specific
Unsaturated Zone Attenuation	Depth to water table dependent	Depth to water table dependent	Depth to water table dependent	Site-specific model
Fate and Transport Models	Default	Default	Default	Alternative
Comparative Concentrations	Maximum	Representative Concentrations- See Appendix C	Representative Concentrations- See Appendix C	Representative Concentrations- See Appendix C
IELCR for Each Chemical & ROE	1×10^{-5}	1×10^{-5}	1×10^{-5}	1×10^{-5}
Hazard Quotient for Each Chemical & ROE	1	1	1	1
Site-wide IELCR	1×10^{-4}	1×10^{-4}	1×10^{-4}	1×10^{-4}
Site-wide Hazard Index	1	1	1	1
Domestic Use of Groundwater Pathway if Complete	MCL or equivalent	MCL or equivalent	MCL or equivalent	MCL or equivalent
Ecological Risk	Compare with WQC in Table 5-1	Evaluate	Evaluate	Evaluate
Outcome of Evaluation	LOC, Tier 1, RMP	LOC, Tier 2, RMP	LOC, Tier 3, RMP	LOC, RMP
Land Use	No	Yes	Yes	Yes

1 Refer to Appendix E

Activity and Use Limitations	None	Depend on land use, groundwater use, and other assumptions in risk assessment

DTL: Default Target Level
LOC: Letter of Completion
ROE: Route of Exposure
IELCR: Individual Excess Lifetime Cancer Risk
MCL: Maximum Contaminant Level
RMP: Risk Management Plan
WQC: Water Quality Criteria

3.1 INTRODUCTION

As discussed in Section 1.0, one of the objectives of the Missouri Risk-Based Corrective Action (MRBCA) process is to provide a department-wide, consistent decision-making process for managing contaminated sites. This framework helps a remediating party and the department answer the following key questions:

1. What is the quality and quantity of data that must be collected at a contaminated site to estimate the risk to human health, public welfare and the environment?
2. How should the data be evaluated to calculate the risks (for example, what models, toxicity values and chemical-physical properties should be used)?
3. If the calculated risks are unacceptable, what risk management activities (active remediations or activity and use limitations) are necessary to reduce risks to acceptable levels?
4. What activities are necessary to ensure that the assumptions used in the calculation of risk remain valid in the future?

Site characterization, risk assessment, and risk management activities help answer the above questions.

As mentioned in Section 1.0, a number of cleanup authorities and programs within Missouri address these very same questions. Therefore, they are reviewed in this section. Specifics of each authority can differ, particularly with reference to terminology; chemicals of concern; public information, notification and participation procedures; documentation of the data collection and risk evaluation activities; administrative reporting; institutional controls; long-term site review requirements; and compliance and enforcement.

This technical guidance does not replace existing federal administrative and statutory requirements. A remediating party should first check with the section of the department under whose jurisdiction the site is being managed to comply with the specifics of program operations.

3.2 MISSOURI DEPARTMENT OF NATURAL RESOURCES

3.2.1 Hazardous Waste Program, Air and Land Protection Division

The Hazardous Waste Program has primary responsibility for remediating contaminated sites under four broad authorities that are managed through five administrative sections, discussed below.

3.2.1.1 Permits Section

The Hazardous Waste Permits Section manages corrective action at Resource Conservation and Recovery Act (RCRA) Treatment, Storage and Disposal (TSD) facilities in Missouri.

Missouri has incorporated the federal corrective action regulations by reference into the state regulations and has been delegated authority by the USEPA to operate the equivalent corrective action program.

The term "corrective action" refers to a process whereby RCRA TSD facilities regulated under the federal RCRA or equivalent state program are required to investigate, monitor and/or remediate releases of hazardous waste and hazardous constituents to the environment. Since 1982, corrective action requirements for releases to groundwater from hazardous waste management (regulated) units have been addressed in accordance with 40 CFR 264.100 [as incorporated by reference in 10 CSR 25-7.264(1)] via the issuance of Missouri hazardous waste management facility or USEPA RCRA permits. Since November 8, 1984, [the effective date of the RCRA Hazardous and Solid Waste Amendments (HSWA)], corrective action requirements for both hazardous (40 CFR 264.100) and solid waste management units (40 CFR 264.101) have been addressed on a case-by-case basis via hazardous waste facility permits, corrective action orders or other agreements.

A flow chart of the Missouri RCRA corrective action process is shown in Figure 3-1.

3.2.1.2 Superfund Section

In 1980, the U.S. Congress established the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), commonly known as Superfund. The federal law provided both response and funding mechanisms for the cleanup of hazardous substance disposal sites. The Superfund program is designed to clean up contaminated property where releases of hazardous substances have occurred in the past or are threatening to occur due to past practices. The federal law requires the past polluters, called responsible parties, to pay for the cleanup. Although the federal CERCLA program is not delegated to the state, the department's Superfund Section has responsibility for many Superfund sites.

In June 1983, a state Superfund bill (Chapters 260.440 through 260.475 RSMo) was approved in Missouri. The law authorized the establishment of emergency response activities in the state to respond to hazardous substance releases and established the Registry of Abandoned and Uncontrolled Hazardous Waste Disposal Sites in Missouri.

A flow chart of the Missouri Superfund process is shown in Figure 3-2.

3.2.1.3 Federal Facilities Section

The Federal Facilities Section provides oversight and review of investigations, management, and remediation of hazardous (chemical and radiological) substances at federal facilities in Missouri. Federal facilities include sites currently or previously owned or operated by the Department of Defense or the Department of Energy. In addition, the Federal Facilities Section provides guidance to ensure that activities conducted at the sites are in accordance with both state and federal environmental laws and regulations. The Federal Facilities Section coordinates with other department programs and state agencies to ensure that human health, public welfare and the environment are protected.

The section predominantly operates under the authority of two federal laws: the Comprehensive Environmental Response, Compensation and Liability Act/Superfund Amendments and Reauthorization Act (CERCLA/SARA) and the Federal Facility Compliance Act (FFCA). CERCLA/SARA oversees the cleanup of hazardous substances. Additional authorities include cooperative agreements under the Defense State Memorandum of Agreement, cooperative agreements with the United States Army Corps of Engineers, and Federal Facilities Agreements.

Authorities for the Remedial Investigations/Feasibility Studies are pursuant to Sections 120 and 121 of CERCLA/SARA, 42 U.S.C §§ 9620 and 9621 and Sections 3006 and 6001 of RCRA, 42 U.S.C §§ 6901 et seq., as adopted in Section 260.350 et seq. and Title 10 CSR, Chapter 25 and Chapter 80.

Authorities for Remedial Actions are pursuant to Sections 120 (f) and 121 (f) of CERCLA/SARA, 42 U.S.C §§ 9620 (f) and 9621 (f) and Sections 3006 of RCRA, 42 U.S.C §§ 6925 as adopted in Section 260.350 et seq. and Title 10 CSR, Chapter 25 and Chapter 80.

Depending on the site, the corrective action process for federal facilities follows either the CERCLA or the RCRA process.

3.2.1.4 Brownfields/Voluntary Cleanup Section

The Brownfields/Voluntary Cleanup Program (B/VCP) provides state oversight for voluntary cleanup of hazardous substance contamination by property owners and others. Environmental assessments of commercial and industrial property are part of many real estate transactions, and are often required by lenders and buyers as a result of the liability provisions of the federal CERCLA, or Superfund, law. If contamination is found, property owners or other interested parties often want to clean up the property and also receive a certificate of completion, no further action letter, or "clean letter" from the state that provides a measure of environmental liability protection. In addition, the contamination may be of a type or concentration that does not warrant enforcement action and may not require cleanup under existing regulations. If so, B/VCP may be the only program with the authority to provide oversight of the cleanup and a certification of completion.

The B/VCP provides guidance to ensure that any cleanup satisfies applicable state and federal regulations and written assurance when the project is complete. Missouri's Hazardous Substance Environmental Remediation Law (voluntary cleanup law – 10 CSR 25-15.010) provides the Hazardous Waste Program's Brownfields/Voluntary Cleanup Section with the resources and the authority to provide project oversight and completion letters. The participant pays oversight costs to the department.

The Missouri Department of Economic Development (DED) grants remediation tax credits for eligible sites undergoing remediation and redevelopment. DED requires a site undergoing remediation, among other things, to be enrolled in B/VCP, and to have a Remedial Action Plan approved by B/VCP.

A flow chart of the Missouri B/VCP process is shown in Figure 3-3. Historically, the risk assessment portion of the B/VCP program shown in Figure 3-3 followed the ***Cleanup Levels in Missouri*** (CALM) guidance document developed by the department in 1998 and updated in September, 2001. The CALM process is similar to the MRBCA in that it incorporates tiered target levels and includes the concept of activity and use limitations and long-term stewardship. When final, the MRBCA technical guidance will replace the CALM document.

3.2.1.5 Tanks Section

The Tanks Section is charged with the oversight of releases of petroleum products from regulated underground storage tanks and from above ground storage tanks that store petroleum products for resale purposes. The risk-based process for petroleum storage tanks is described in the most recent edition of the guidance, **Missouri Risk-Based Correction Action (MRBCA) for Petroleum Storage Tanks.** This guidance was developed to implement release investigation and corrective action regulations found at 10 CSR 20-10 and 10 CSR 20-15. The authority to regulate these releases is found at Sections 319.100 - 319.139, RSMo.

The Tanks MRBCA process is similar, but not identical, to the process described in this document. The cleanup standards from the Tanks MRBCA may be applied to petroleum product releases from other sources unless such releases are subject to RCRA Subtitle C or CERCLA. In such instances, the application of RCRA or CERCLA may result in different cleanup standards. In either case, however, the corrective action should follow the procedures in this guidance, including any activity and use limitations.

3.2.2 Solid Waste Management Program, Air and Land Protection Division

The Solid Waste Management Program (SWMP) implements state laws passed by the Missouri legislature, state regulations and policies developed by department staff and the USEPA in regard to solid waste management. The SWMP staff:

- Provides administrative and technical assistance,
- Issues permits for solid waste disposal and processing facilities,
- Reviews engineering plans and specifications for new facilities and changes at existing facilities,
- Inspects and enforces state solid waste management law, regulations, and permit conditions,
- Requires corrective action at landfills as appropriate,
- Administers a statewide grant program to promote the reduction of solid waste, and
- Oversees the Solid Waste Management Districts.

The SWMP administers these authorities under the Missouri Solid Waste Management Law, Sections 260.003 through 260.345 RSMo and under federal RCRA statutes and regulations. The solid waste management regulations are found in 10 CSR 80. Federal authority is found in Subpart D of RCRA.

3.2.3 Land Reclamation Program , Air and Land Protection Division

The Land Reclamation Program implements state laws, regulations and policies developed by the Land Reclamation Commission to reclaim lands affected by mining of various mineral commodities. The staff provides administrative and technical assistance to the commission, issues and monitors mining permits, reviews engineering plans and specifications for new facilities, monitors reclamation progress, enforces permit conditions and state mining regulations, and administers the federal abandoned mine lands grant to reclaim properties affected by historic mining in Missouri.

Section 503(a) of the Surface Mining Control and Reclamation Act (Public Law 95-87) allows the United States Department of Interior Office of Surface Mining to delegate coal mining regulatory authority to the states. For Missouri, this delegation is temporarily suspended due to budgetary constraints.

The Missouri Land Reclamation Commission administers these authorities under both the Missouri Surface Mining Law and the Land Reclamation Act (RSMo 444). The program also administers the Metallic Minerals Law (for the department, not the Commission), also in RSMo 444. The powers and duties of the Commission can be found in RSMo 444.762 and 444.767 and include striking a balance between the surface mining of minerals, the reclamation of the land, and the protection of the state wildlife and aquatic resources.

3.2.4 Water Protection Program, Water and Soil Conservation Division

The Water Pollution Control Branch of the Water Protection Program implements state laws, regulations, and policies developed by the Clean Water Commission to maintain and improve water quality. The staff provides administrative and technical assistance to the commission; issues and monitors wastewater discharge permits; reviews engineering plans and specifications for new facilities; monitors and assesses water quality; enforces permit conditions and state water quality regulations; and administers grants and loans for the construction of wastewater treatment facilities.

Section 402(b) of the Clean Water Act allows the USEPA to authorize the National Pollutant Discharge Elimination System (NPDES) Permit Program to the states. Section 303(c) of the Clean Water Act requires state governments to periodically review and revise its water quality standards.

The Missouri Clean Water Commission administers these authorities under Missouri Clean Water Law (RSMo 644). The powers and duties of the Commission can be found in RSMo 644.026 and include development of water quality standards [1. (7)] and implementation of the NPDES permit program [1. (13)].

Within the MRBCA process, the Water Protection Program may provide assistance at sites where impacts may migrate to a surface water body. A Memorandum of Understanding governs much of the interaction between the Water Protection and Hazardous Waste

Programs.

3.3 MISSOURI DEPARTMENT OF HEALTH AND SENIOR SERVICES

3.3.1 Section for Environmental Public Health, Division of Environmental Health and Communicable Disease Prevention

The Section for Environmental Public Health implements state laws, regulations, and policies to protect the public health through identification, prevention of disease, and evaluation of exposures to toxic chemical and radioactive substances. The staff provides technical assistance to the Department of Natural Resources by preparing or reviewing quantitative human health risk assessments, public health assessments, health studies, and health consultations for hazardous waste sites or hazardous substances.

Under state statute, 192.011 RSMo, the Department of Health and Senior Services (DHSS) monitors the adverse human health effects of the environment and prepares population risk assessments regarding environmental hazards, including those relating to water, air, toxic waste, solid waste, sewage disposal and others. DHSS makes recommendations to the Missouri Department of Natural Resources for improvement of public health as related to the environment. Under state statute 260.445.5 and 260.480.2(2) RSMo, DHSS evaluates the human health effects of abandoned or uncontrolled hazardous waste sites and of releases of hazardous substances as defined in 260.500 RSMo. Evaluations can include immediate public health investigatory response to actual or potential environmental contamination, assessing risk of exposure to hazardous substances, and advice on suitability of different remedial activities to reduce or eliminate human health hazards.

4.1 IDENTIFICATION OF IMMINENT THREAT

When there is a confirmed release or a suspicion of a release, the first step is to determine if any imminent threats or hazards exist. Examples of imminent threats are impacts to existing water supply wells, contaminant vapors in inhabited enclosed spaces at levels that could result in an explosion, and free product on a surface water body. In some cases, imminent threats may be identified prior to discovery of the source of the contaminant release.

In all cases, the department must be notified immediately about suspected or confirmed imminent threats as discussed below.

4.2 NOTIFICATION OF IMMINENT THREAT

All emergency response activities are conducted under Sections 260.500 through 260.550, RSMo 2000 and the regulations promulgated there under. Upon discovery of an emergency involving a hazardous substance, any person (as defined in RSMo 260.500) having control over a hazardous substance must contact the department by calling (573) 634-2436 as soon as possible.

As defined in these statutes and administered by the department's Environmental Services Program (ESP):

- A hazardous substance emergency refers to any release of hazardous substances equal to or in excess of those determined pursuant to Section 101(14) or 102 of the federal Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended, and Section 304 of the Superfund Amendments and Reauthorization Act of 1986.
- A hazardous substance is defined as any substance or mixture of substances that presents a danger to the public health or safety or the environment. However, radioactive materials, wastes, emissions or discharges licensed or regulated by the federal government or the state of Missouri are not considered hazardous substances unless they are released as a result of a transportation accident; and
- Any release of petroleum in excess of 50 gallons (25 gallons for USTs) is a hazardous substance emergency.

After a release is reported, the department will evaluate whether an imminent threat exists and it may require any reasonable actions to end the hazardous substance emergency. The department may also require that actions be taken to prevent recurrence of the hazardous substance emergency. In the event that the person having control of the substance fails to act, the department may take action and pursue recovery of its costs.

Upon completion and documentation of the emergency response activities, and if the release of a hazardous substance is confirmed, additional data may be needed to perform a risk-based evaluation and to receive a Letter of Completion.

If a hazardous substance emergency exists or is likely to occur, the department will not approve a risk assessment or Risk Management Plan unless imminent threats are abated.

4.3 MITIGATION OF IMMINENT THREATS/EMERGENCY RESPONSE ACTIONS

4.3.1 Actions to Mitigate Immediate Impacts

Specific mitigation actions depend on the nature of the imminent threat. For example, if a drinking water well were impacted, actions would include immediate notification to the users of the well and provision of an alternative water supply. Identification of vapors in a structure may require immediate evacuation of any individuals in the structure, ventilation of the structure, and restrictions on entry until the threat has been adequately abated.

4.3.2 Actions to Prevent Further Deterioration

After abatement of immediate threat(s), actions must be undertaken to prevent any further deterioration of the situation. Examples of such actions are:

- Identify the product or chemicals released and the source of release,
- Carefully handle any excavated materials or other contaminated media to avoid human contact as well as to avoid spreading contamination,
- As soon as possible, remove any light, non-aqueous phase product floating on groundwater or surface water or that has collected in excavations, and
- Prevent further spread of the release.

4.3.3 Actions to Prevent Long-Term Impacts

After abatement of imminent threat(s), the owner/operator is required to begin activities to prevent long-term adverse impacts. Actions may include the continued provision of alternate water supplies to the affected parties or a detailed site characterization and the performance of a MRBCA evaluation to determine the need for any corrective action. Some of these actions may involve periodic activities over an extended period of time. Examples include:

- Periodic testing of water supply well(s),
- Periodic testing of vapors in impacted structures,
- Removal of free product, and
- Maintenance of any point-of-use treatment system(s).

4.4 DOCUMENTATION OF RESPONSE ACTIVITIES

Upon completion of Emergency Response Activities, the remediating party must submit a Hazard Abatement Report that, at a minimum, includes the following:

- Nature of the hazard identified,

- Details of the activities conducted,
- Details of any follow-up periodic activities (for example, periodic replacement of carbon filters if water supply wells have been affected), and
- Details of recommended actions, such as site characterization.

The report should include text, figures, and tables as appropriate.

5.0
INITIAL CHARACTERIZATION AND COMPARISON WITH DEFAULT TARGET LEVELS AND WATER QUALITY CRITERIA

5.1 MRBCA OBJECTIVE OF INITIAL SITE CHARACTERIZATION

With respect to the MRBCA process, the objective of an initial site characterization is to collect sufficient data to determine whether:
- The site qualifies for a Letter of Completion,
- An ecological risk exists,
- The preferred remediation alternative will be to default target levels (DTLs) and/or applicable water quality criteria, or
- The site will move to a Tier 1, Tier 2, or Tier 3 assessment.

Which of the above four alternatives is selected will depend on a variety of site-specific and economic factors. For sites with small, localized impacts and no ecological risks, remediation to DTLs may be the most cost-effective option. A brief description of the initial site characterization process is presented below.

5.2 SITE DESCRIPTION

The remediating party should conduct a thorough site reconnaissance and a historic review of site use and site operations to identify past, existing and potential sources of contamination. This description would be based on available information such as:
- Knowledge of known or documented releases,
- Current and past location of certain structures that represent potential sources (for example, pipelines, process areas, pumps, or transformers),
- Historical aerial photographs, fire insurance maps, etc.,
- Interviews with current and past owners and operators,
- Permits issued for various activities, and
- One or more site visits.

Based on this information, the remediating party should prepare a list of potential chemicals of concern (COCs) and the probable location of sources of COCs. It may be useful to develop an initial conceptual site model to optimize sampling design in order to develop the initial characterization work plan.

5.3 COLLECTION OF DATA

Prior to the collection of any environmental data, the remediating party must submit the Initial Characterization and Data Collection Work Plan to the department for review and approval. The work plan must meet the minimum Data Quality Assurance/Quality Control requirements of the department's Quality Management Plan (See Appendix K for more information). After approval, the remediating party should implement the work plan and collect samples of environmental media in areas that are representative of the maximum concentrations. At sites with multiple discrete sources, data should be collected for each of the sources. The exact number of samples, analytical methods, field sampling techniques, and quality assurance/quality control (QA/QC) samples to be collected will vary from site to site. The objective is to identify with certainty the maximum concentrations of the COCs in each impacted environmental media. However, for sites that may require additional characterization or remediation, it may be more cost effective at this point to delineate the nature and extent of impacts rather than only identifying the highest concentrations.

During the course of investigation, the analytical detection limit for certain COCs in environmental media may be higher (sometimes by orders of magnitude) than the corresponding DTL or Tier 1 RBTL for that chemical. This happens because the concentration of chemicals that can be positively detected in the environmental media (soil, groundwater, sediments, and air) are limited by the capabilities of the analytical method used.

For information purposes, the following have been identified in Appendix B:
- COCs with DTLs or Tier 1 RBTLs lower than the detection limit or Practical Quantitation Limit (PQL) of current analytical methods and
- COCs that do not have a standard method listed in SW-846.

This discussion identifies the approaches that may be used to characterize sites where the DTL, Tier 1 RBTL, or other investigative screening level for a particular COC(s) cannot be achieved using standard analytical methods. Examples of these approaches include:
1. Check the data to confirm that the standard detection limits are indeed higher than the DTLs or RBTLs and that no errors were committed in any of the processes (for example, transposing numbers, misplacing a decimal point, or unit conversion).
2. Use alternative analytical methods that achieve lower detection limits than the target levels.
3. Use other associated COCs as surrogates for contaminant extent determination, provided that the environmental mobility of the problem chemical(s) is equal to or less than the surrogate's mobility. Where multiple surrogates are possible, select the one with the mobility closest to the problem chemical.
4. Use data that are above the analytical detection limit for COCs with low DTL values to develop areal contaminant trends which can then be used to extrapolate contaminant extent to the DTLs.
5. Use data that are above the analytical detection limit in a fate and transport model to extrapolate contaminant extent.
6. Determine the exposure pathway that was used to estimate the DTLs. If that pathway is not complete for the site, and with prior departmental approval, use alternative exposure pathway-based investigatory threshold levels.

This is not an exhaustive list of approaches. These and other reasonable approaches will be considered by the department and can be approved on a case-by-case basis.

5.4 COMPARISON WITH DEFAULT TARGET LEVELS AND WATER QUALITY CRITERIA

Figure 5-1 illustrates the decision process to determine the next course of action. This determination is based on both human health and ecological risks.

To determine if an ecological risk exists at the site at the default target level, it is necessary to use Table 5-1 (compiled from Missouri's Water Quality Standards, 10 CSR 20-7.031) to answer the following questions. (Note that Tiers 1, 2, and 3 require a screening mechanism, discussed in Section 6.) This table lists the chemicals for which water quality criteria found in the Water Quality Standards are lower than the domestic use of groundwater standard or for which no domestic groundwater use standard exists.

> *Question 1*: Are any of the COCs detected in groundwater listed in Table 5-1? If not, no further ecological evaluation is necessary because, for any other chemicals with Tier 1 risk-based target levels, the water quality criteria for an ecological receptor is higher than the human health value listed in the DTL table in Appendix B. However, a yes response for any one of the chemicals in Table 5-1 implies the possibility of ecological impacts; therefore, the second question must be answered.
>
> *Question 2*: Does the maximum concentration of any of the COCs found in Table 5-1 exceed its water quality criteria? If not, then no further ecological evaluation is necessary. However, if the maximum concentration for any one of these chemicals exceeds its water quality criteria, then it is necessary to determine if there are any complete pathways for ecological receptors; therefore, the next question must be answered.
>
> *Question 3*: Do any ecological receptors that would result in a complete exposure pathway exist at or near the site? This can be determined by completing the Level 1 Ecological Risk Assessment discussed in Section 6.0 and, if necessary, proceeding to Level 2 and 3.

After completing the Ecological Risk Assessment and any further ecological evaluation required by the department, if ecological issues exist, then the maximum groundwater concentrations must be compared with the lower of the DTLs or the applicable water quality criteria (only for the chemicals listed in Table 5-1).

For both ecological and human health risk assessment, the maximum soil and groundwater concentrations must also be compared with the default target levels (DTLs) presented in Appendix B. If the maximum soil and groundwater concentrations do not exceed the DTLs and no ecological risk is identified, the remediating party may petition the department for a Letter of Completion.

If either the soil or groundwater maximum concentrations exceed its comparative value, the remediating party has two alternatives:

1. Conduct a Tier 1, Tier 2, or Tier 3 evaluation, or

2. Select the DTLs (or lower of DTLs and water quality criteria if ecological issues are of concern) as the cleanup levels. In this case the remediating party must develop a Risk Management Plan as discussed in Section 12.

5.5 INITIAL CHARACTERIZATION REPORT

The remediating party should document the results of the initial characterization and comparison with target levels in a report to the department. The report should discuss:

- Site history,
- Site description,
- Current site use,
- Sources and COCs identified at the site,
- Methods used to collect data,
- Locations and concentrations of all samples (identified on a site map), including sample depths,
- Laboratory results from chemical data analysis,
- Locations, construction and lithology of all borings, wells or piezometers,
- QA/QC information,
- Determination of whether ecological issues are of concern,
- Results of comparison with DTLs and applicable water quality criteria, and
- Recommendation for the next course of action (request for Letter of Completion, remediation, or tiered assessment).

6.0
DEVELOPMENT AND VALIDATION OF CONCEPTUAL SITE MODEL

6.1 INTRODUCTION

This section discusses a systematic planning process for data collection activities for site characterization for Tier 1, 2, and 3 risk assessments. Environmental data used in the Missouri Risk-Based Corrective Action (MRBCA) process must be scientifically valid, defensible, and of known and documented quality. This can be achieved by the use of adequate quality assurance and quality control procedures throughout the entire process (from initial study planning through data usage). This section briefly discusses techniques used to collect the data, but references are cited to provide more detailed information about methodologies for the collection of data.

In the MRBCA process, data is used to:

- Develop and validate a conceptual site model,
- Delineate the extent of impacts in each media necessary to quantify the risk to receptors,
- Identify the maximum media-specific site concentrations,
- Identify the exposure domains for each complete receptor-pathway-route of exposure,
- Estimate the representative concentration for each exposure domain,
- Develop a feasible risk management plan, if necessary, and
- Confirm the effectiveness of risk management alternatives.

6.2 COMPONENTS OF CONCEPTUAL SITE MODEL

On a given project, different individuals may collect data over a long period of time. Therefore, it is important to compile the relevant data in a format that is easy to understand and use. A conceptual site model provides a convenient format to present an overall understanding of the site. A conceptual site model may be developed at the start of a project and refined and up-dated throughout the life of the site activities. A complete and detailed conceptual model is essential to making sound professional judgements about sampling design and for optimizing that design. It can help identify the pros and cons of various remediation activities or activity and use limitations. Finally, it is an important communication tool for regulators, remediating parties and stakeholders.

A conceptual site model can be prepared using available information for the site together with an applicable guidance document such as ***Guidance for the Data Quality Objectives Process*** (EPA QA/GW, August 2000) and ***Data Quality Objectives Process for Hazardous Waste Site Investigations*** (EPA QA/G-4HW, January 2000).

Key elements of the conceptual site model include:

1. The chemical release scenario, source(s), and chemicals of concern (COCs),
2. Spatial and temporal distribution of COCs in the various affected media,
3. Current and future land and groundwater use,
4. Description of any known existing or proposed land or water use restrictions,

5. Description of site stratigraphy, determination of the predominant vadose zone soil type, hydrogeology, meteorology, and surface water bodies that may potentially be affected by site COCs,
6. Remedial activities conducted to date, and
7. An exposure model that identifies the receptors, pathways and routes of exposure under current and future land use conditions.

To adequately characterize a site to determine risks, the following categories of data may be required:

- Site information, as defined in Section 6.3,
- Description and magnitude of the spill or release, as defined in Section 6.4,
- Adjacent land use, activity and use limitations, and receptor information, as defined in Section 6.5,
- Analysis of current and future groundwater use, as defined in Section 6.6,
- Vadose zone soil characteristics, as defined in Section 6.7,
- Characteristics of saturated zones, as defined in Section 6.8,
- Surface water body characteristics, as defined in Section 6.9,
- Ecological risk assessment, as defined in Section 6.11,
- Meteorology (such as rainfall, infiltration rate, evapotranspiration, wind speed and direction),
- Distribution of chemicals of concern in soil, as discussed in Section 6.12,
- Distribution of chemicals of concern in groundwater, as discussed in Section 6.13,
- Distribution of chemicals of concern in soil vapor, as discussed in Section 6.14, and
- Distribution of chemicals of concern in sediments and surface water bodies, as discussed in Section 6.15.

As part of the MRBCA evaluation, the remediating party must carefully review all the available data and identify any data gaps. A systematic planning process is used to develop a work plan to be approved by the department. To fill in data gaps, the work plan must include: (i) a sampling and analysis plan and (ii) a Quality Assurance Project Plan (QAPP) that meets *EPA Requirements for Quality Assurance Project Plans (EPA QA/R5)* along with *EPA Guidance for Quality Assurance Project Plans (EPA QA/G5)* (QAPPs can be site specific or activity specific). The objectives of the QAPP and the Sampling and Analysis Plan components of the work plan are to ensure that:

- The intended use of the data is clearly defined and understood to ensure that the collected data will be of adequate quality and quantity,
- All environmental data used to make risk assessment and risk management decisions is scientifically valid, defensible and of known quality,
- The specific location where samples will be collected, the handling requirements for the samples, and methods of analysis are clearly specified to avoid any confusion or ambiguity once the field work begins, and
- All data collected is consistent with the Quality Management Plan for the Missouri Department of Natural Resources.

The remediating party can only use or develop target levels, calculate representative concentrations, prepare a risk assessment, and prepare a risk management plan after all the necessary data has been collected.

6.3 SITE INFORMATION

The term "site" refers to the areal extent of contamination where the spill or release occurred. Areas beyond the site that may be impacted by the site chemicals are referred to as the "off-site" areas.

The following information is necessary to complete an MRBCA conceptual site model:
- A site location map,
- A site map,
- Ground surface conditions,
- Location of utilities on and adjacent to the site,
- On-site groundwater use, and
- Local hydrogeology and aquifer characteristics.

A brief discussion of each of the above items is presented below. Relevant site information can be obtained by various means, including:
- Site visits,
- Deed search,
- Historical records and aerial photographs,
- Review of engineering drawings showing the layout of the site,
- Review of regional information,
- Review of files at the department related to the site or adjacent sites, and
- Contact with the city, municipality or other governing agencies to identify any existing land use requirements, such as zoning.

6.3.1 Site Location Map

A site location map must be prepared using United States Geological Survey (USGS) 7½ minute topographic maps as a base. The site location should be centered on the topographic map (cropping the maps as necessary), with the location clearly marked. Contour lines on the topographic map must be legible.

6.3.2 Site Map

A detailed map(s) of the site should show:
- Property boundaries,
- Layout of past and current site features such as containment or storage systems; process areas; transportation and delivery distribution systems; waste handling and storage areas, including associated components and piping runs; sumps; paved and unpaved areas; and buildings,
- Locations of area(s) of release,
- Locations of on-site monitoring wells (including those that have been abandoned,

identified in some way but for which exact information is missing, or destroyed),
- Locations of water wells (public and private),
- Location of surface water features,
- Ecological or terrestrial sensitive features, and
- Locations of soil borings, soil vapor extraction wells, and soil excavation areas.

Multiple maps showing these features may be necessary.

Site maps must be drawn to scale and include a bar scale and a north arrow. In addition to the site map(s), a land use map is also required (refer to Section 6.5.1).

6.3.3 Ground Surface Conditions

Identify the portion of the site that is paved, unpaved or landscaped. Note the type, extent, date of installation, and general condition of the pavement. Describe the unpaved areas (for example, vegetated, gravel, or bare soil). Determine the direction in which the surface is sloping and note relevant topographic features (for example, swales, drainage, or detention ponds).

6.3.4 Location of Utilities On and Adjacent to the Site

Contaminated groundwater and vapors can flow preferentially into and through underground utility lines and conduits and thereby increase the probability of utility workers being exposed. Therefore, a thorough assessment of potential and actual migration and impacts of COCs to underground utilities must be performed. Utilities include cable and telephone lines, sanitary and storm sewers, and water and natural gas lines. A combination of site observations, knowledge of buried utilities, and discussions with utility representatives (or use of a one-call system) and the site owner should be used to determine the location of site utilities. At a minimum, the following must be performed:

- If explosive conditions are encountered, immediately inform the local fire department and the department Emergency Response Spill Line at (573) 634-2436.
- Locate all underground utility lines and conduits within the area of known or suspected soil and groundwater impact, both on- and off-site, where the release may have migrated or may migrate in the future.

Then, if available and if utilities are located in the area of contamination, the following information may be useful in the analysis:

- Direction of water flow in utility lines (potable water, storm water, and sewage).
- Location of the utility lines and conduits on a base map that shows the extent and thickness of non-aqueous phase liquid (NAPL), free product, if any, and soil and groundwater contamination.
- Depth of the utility lines and conduits relative to the depth of groundwater. Seasonal fluctuations of groundwater levels (relative to the depth of utilities) must be carefully evaluated. A cross-sectional diagram that illustrates the depth to groundwater and the locations and depths of the utility lines and conduits is recommended.

- Types of materials used for utility lines and conduits - for example, polyvinyl chloride (PVC), terra cotta, concrete or steel - and the type of backfill around the utilities.
- Any historical work completed on any of the utilities and if any contamination-related issues were identified at the time the work was performed.

6.3.5 On-site Groundwater Use

Current and former site owners and operators should be interviewed to determine whether any water well(s) is or was located on site. Any and all wells will need to be identified based on a search of local, state and federal records and databases and/or windshield or door-to-door surveys, as appropriate. The level of effort necessary will be especially critical for the department to make a determination whether the domestic use of groundwater pathway is complete or incomplete.

To the extent that such information is available, the remediating party must provide well construction details for all wells identified. Relevant construction details include the total depth of the well, casing depth, screened or open interval, static and/or pumping level, and the use of water from the well. If available, average well pumping rates and drawdown information also should be provided.

If an identified well is not currently in use or likely to be used in the future, it may be closed in accordance with department requirements. Sections 256.603(1) and 256.637.4 RSMo. of the Missouri Water Well Driller's Act provides information on abandoning and plugging wells under conditions of disrepair and hazardous conditions.

6.3.6 Local Hydrogeology and Aquifer Characteristics

Local hydrogeology, soil types and aquifer characteristics should be evaluated to determine the type and depth of aquifers in the area and whether they are confined, semi-confined or unconfined. This information can be found in published literature - especially United States Geological Survey (USGS) and Geological Survey and Resource Assessment Division (GSRAD) publications and in United States Department of Agriculture (USDA) soil surveys - and reports for any investigations conducted at adjacent or nearby release sites. General aquifer characteristics such as yield and total dissolved solids will help determine whether the domestic consumption exposure pathway is a concern. The remediating party should use regional information to better understand site-specific soil and groundwater conditions.

The Missouri Environmental Geology Atlas (MEGA), developed by the department in association with the Missouri Petroleum Storage Tank Insurance Fund, is a valuable, though not the only, source for regional hydrogeology and aquifer characteristics. The MEGA can be obtained for a nominal cost from the department's Geological Survey and Resource Assessment Division by calling (573) 368-2101.

The review discussed above should also identify surface water bodies (lakes, rivers and streams, and wetlands), seeps, caves, sinkholes and springs located within a distance that is or could be affected by a release at the site. Water bodies must be identified on the area map discussed in 6.5.1. In karst areas, the department may require a larger search area.

6.4 DESCRIPTION AND MAGNITUDE OF SPILL OR RELEASE

Knowledge about the nature, location and magnitude of a release(s) is necessary to identify the:

- Soil and groundwater source(s) at the site,
- Chemicals of concern,
- Methods that will be used to analyze the samples, and
- Horizontal and vertical extent of soil and groundwater contamination.

The remediating party must collect as much of the following information as is available for each release that has occurred at the site:

- History of site activities related to the release,
- Location(s) and date(s) of spill(s) or release(s),
- Quantity of the release(s),
- Product(s) or chemical(s) released, and
- Interim response or corrective action measure(s) taken with respect to each release.

Release-related information can be obtained from a variety of sources, including:

- Review of historical aerial photographs or Sanborn fire insurance maps
- Review of product or waste inventory records,
- Interviews with past and current on-site employees,
- Review of the department's Hazardous Waste or Water Protection Program files,
- Review of USEPA files,
- Review of historic spill incident reports filed with the department,
- Review of permits, and
- Review of administrative or consent orders related to the site.

6.4.1 History of Activities at the Site

At many contaminated sites, one or more site investigations, monitoring events, system (such as tanks, pipelines, or lagoons) removal activities, or remediation activities may have taken place over an extended period of time.

Therefore, a key step in the MRBCA process is to develop a comprehensive chronology of historical events related to any chemical impacts. A chronology will help create a complete picture of the site activities and identify COC and data collection needs. The chronology should include information such as the dates, descriptions and results of:

- Installation, removal or upgrade of containment, process, delivery or waste systems,
- Remedial activities such as excavation and disposal of contaminated soil,
- Drilling, sampling and gauging of monitoring wells, and
- Collection of environmental media samples.

Interim response actions may have removed all or part of the COCs released at a site. Soil and groundwater data collected prior to the completion of these activities may not be representative of current conditions and should not be used in the calculation of current exposure and risk. At such sites, the remediating party must collect additional soil and groundwater concentration data representative of current conditions. However, data collected prior to the completion of interim action(s) may be used to guide decisions on additional data collection.

The intent of developing a site history is to clearly understand site activities in order to develop a conceptual site model that can be used to accurately assess any associated current and future risks.

6.4.2 Location and Date of Spill or Release

The identification of the location of a release helps define the source area(s). Likely release locations at contaminated sites include:

- Corroded or damaged containment or process system components,
- Piping, especially at pipe bends and joints,
- Dispenser and delivery systems,
- Deposition near smoke stacks or air discharge points,
- Accidental releases at areas for receiving, delivering, or handling chemicals and wastes,
- Waste water lagoons and run-off basins,
- Waste storage and disposal areas, and
- Hazardous product materials storage areas.

A release may occur within the surficial soil. Surficial soil is the zone that a receptor could directly come into contact with and be exposed to COCs in the soil by ingestion, dermal contact, or inhalation of particulates. In the MRBCA process, for both residential and non-residential receptors, surficial soil is defined as from 0 to 3 feet below ground surface (bgs). Subsurface soil is defined as from 3 feet bgs to the water table. If the groundwater is less than 3 feet bgs, then the surficial soil extends to the depth of the water table and there is no subsurface soil.

Based on the site chronology and operational history described in Section 6.4.1, the remediating party may be able to determine the location and date of the release(s). However, often the exact location and date of the release(s) cannot be known. In such cases, field screening, such as the use of a photoionization detector (PID), x-ray fluorescence (XRF) spectrophotometer, field bioassays, and/or collection of samples for laboratory analysis must be used to identify the likely location and extent (vertical and horizontal) of COCs in the soil and groundwater. Decisions regarding the use and application of field screening technologies and collection of samples must be based on site-specific conditions and chemicals. For example, PIDs may not be accurate for soils above a certain moisture content, and the PID does not detect all types of chemicals. Visual observations may be used to identify soil sample locations. This information is part of a sampling and analysis plan.

6.4.3 Quantity of Spill or Release

The MRBCA process does not necessarily require knowledge of the exact quantity of the released chemicals or wastes. Often this information is not known. However, having a general idea of the amount released can assist in assessing the potential extent and severity of a chemical impact. Approximate amounts may also be used to provide the basis for any chemical mass balance calculations.

6.4.4 Product(s) or Chemical(s) Released

The MRBCA process primarily focuses on developing risk-based target levels for individual chemicals. However, target levels may at times be developed for products or wastes that are mixtures of chemicals such as oil, gasoline, deicing agent, Stoddard solvent, polychlorinated biphenyls (PCBs), and polychlorinated dioxin. The remediating party must identify the COCs comprising such products or wastes. For chemicals related to petroleum product spills, refer to the most recent version of the ***Missouri Risk-Based Corrective Action (MRBCA) Process for Petroleum Storage Tanks***.

6.5 ADJACENT LAND USE, ACTIVITY AND USE LIMITATIONS, AND RECEPTOR INFORMATION

Land use information is used to identify the (i) location and type of potential receptors, (ii) routes of exposure by which the potential receptors may be exposed to the COCs, and (iii) presence of any site activity and use limitations (AULs) that may affect the completion of exposure pathways. This information is critical in developing a site exposure model. Specifically, the following information must be collected:

- Current land use and zoning,
- Potential future land use and zoning,
- Local ordinances, easements and restrictions that affect land or groundwater use,
- Quality and availability of potable water supplies,
- Off-site groundwater use, and
- Ecological receptor survey.

At a minimum, the department will require a land use and receptor survey covering the entire contaminated and potentially contaminated area.

6.5.1 Current Land Use

Knowledge of the uses of the site and nearby properties is necessary to define potential on-site and off-site receptors that may be exposed to the COCs. A visual, on-site land use reconnaissance survey within the area of impact must be conducted to avoid ambiguity about site uses. The survey must clearly identify the following: schools, hospitals, residences (apartments, condominiums, townhouses, and single-family homes), buildings with basements, day care centers, churches, nursing homes, and types of businesses. The survey must also identify surface water bodies, parks, recreational areas, wildlife sanctuaries, wetlands and agricultural areas. The results of the survey must be accurately documented on a land use map. Figure 6-1 is a sample land use map.

The land use map need not be drawn to an exact scale; in most cases, an approximate scale will suffice. However, a north arrow on the map is required.

6.5.2 Future Land Use

Future land use and receptors must be established, which are more difficult to determine than current land use and receptors. Unless future land use is known and can be documented (for example, by development plans or building permits), predictions of future use must be based on local zoning laws and surrounding land use patterns. As appropriate, zoning maps, aerial photographs, local planning offices, the U.S. Bureau of the Census, community master plans, changing land use patterns, and interviews with current property owners can provide information with which future land use can be predicted. Proximity to wetlands, critical habitat and other environmentally sensitive areas must also be considered in predicting future land uses.

6.5.3 Off-site Groundwater Use

A water well survey must be conducted to locate all public water supply wells within a one-mile radius of the site and all private water wells within a quarter-mile radius of the site. (These distances may vary among federal authorities and will also be dependent on COC mobility and hydrogeology.) A few of these wells may be known prior to the water well survey, others may be identified during the survey. The primary repository of well-related information is within the department's Geological Survey and Resource Assessment Division, which maintains records of known pre-law wells and wells drilled in Missouri since enactment of the Water Well Driller's Act of 1985. Other information sources include the USGS, water system operators, and interviews with local residents.

The level of effort expended in a well survey depends on site-specific considerations. It can extend to searches of local, state and federal records and databases and windshield or door-to-door surveys. For example, in newly developed urban areas with a municipal water supply, a door-to-door survey might not be necessary. However, in rural areas where groundwater is the primary source of water or in older developed areas, a door-to-door survey may be needed. The level of effort for this task is especially critical if the department is to evaluate the domestic consumption pathway during the risk assessment process.

As in Section 6.3.4 for on-site wells, to the extent that such information is available, the remediating party must provide well construction details for all wells identified. Relevant construction details include the total depth of the well, casing depth, screened or open interval, static and/or pumping level, and the use of water from the well. If available, average well pumping rates and drawdown information also should be provided.

6.5.4 Ecological Receptor Survey

Ecological receptors include both specific species and general populations of flora and fauna and their habitats, including wetlands, surface water bodies, sensitive habitats, and threatened and endangered species. The Ecological Risk Assessment, Level 1, Checklist A (Appendix F), is a screening tool that must be completed for a Tier 1, Tier 2, or Tier 3 risk assessment. An Ecological Risk Assessment may also be required at the Default Target Level if certain COCs are present at a site (see Section 5.4). Accurate information on the checklist may require that the area around the site be visually surveyed for the specific ecological receptor criteria. The department will require that a visual survey be conducted if a checklist cannot be completed based on existing information.

Refer to Section 6.11 for further information regarding ecological risk assessment.

6.6 ANALYSIS OF CURRENT AND FUTURE GROUNDWATER USE

Impacts to groundwater and potential exposures via the domestic use of groundwater are of significant concern in Missouri because a large part of the state obtains drinking water from groundwater sources. The MRBCA process can be used in cases where groundwater has been contaminated or is likely to be contaminated by a site-specific release. The process has the following objectives:

- To protect all current and reasonably likely future uses of groundwater,
- To provide a rational basis for incorporating site-specific characteristics into the determination of groundwater target levels, and
- To facilitate the development of properties based on reasonable expectations for groundwater cleanup.

A key determination in developing risk-based groundwater target levels is if the groundwater domestic use pathway is complete under current or future conditions. The process used to make this determination is shown in Figure 6-2 and discussed below. The analysis of current and future groundwater domestic use must include all groundwater zones beneath or in the vicinity of the site that could potentially be (i) impacted by site-specific COCs, or (ii) targeted in the future for the installation of water use wells. For the purposes of this analysis, groundwater-bearing zones must be evaluated in a three dimensional context.

As a part of this step, other groundwater uses (for example, cooling water, irrigation, livestock watering, and industrial process water) must also be identified and documented.

6.6.1 Current Groundwater Use

The current groundwater domestic consumption pathway is considered complete if water use wells are located on or near the site and the wells may be impacted by site-specific chemical releases.

Whether a well may be impacted depends on the hydrogeological conditions, well construction and use of the well, including the following factors:

- Characteristics of soil and rock formations,
- Groundwater flow direction,
- Hydraulic conductivity,

- Distance to the well,
- The zone where the well is screened,
- Casing of the well,
- Zone(s) of influence and capture generated by well pumpage, and
- Biodegradability and other physical and chemical properties of the COCs.

If it is determined that any groundwater zone will not be impacted, then justification for this determination should be provided in any tiered risk assessment report and in the Risk Management Plan.

6.6.2 Future Groundwater Use

For each zone, determining if the future groundwater use pathway is complete or likely to be complete is based on consideration of the following factors. All of these factors should be evaluated on a "weight of evidence" basis; the weight that a single factor will be given in determining the probability of future groundwater use will vary based on site-specific considerations, including the durability of any AULs.

Evaluation of Activity and Use Limitations (AULs): If an AUL is in place that minimizes or eliminates the potential that a specified groundwater zone will serve as a future source of domestic water, the presence of the AUL will be considered along with other relevant site-specific domestic consumption factors. For early relief from consideration of this pathway, an ordinance that prohibits well drilling along with a Memorandum of Agreement with a governing body (discussed further in Section 11) can be used to justify an incomplete pathway.

The degree to which AULs will affect the determination will depend on the attributes of the specific AUL. If the attributes of the AUL are not applicable to the situation, durable, or enforceable, a groundwater zone may remain a probable future domestic water source, despite the existence of the AUL.

If the AUL does not explicitly apply to a specific water-bearing zone and that zone meets each of the following criteria, a groundwater zone is considered to have a reasonable probability of future use if:

- The zone is the highest quality groundwater resource (considering both yield and natural quality) in the hydrostratigraphic column.
- The zone has sufficient quality and yield to serve as a primary component of a public or private water supply.
- The zone has no widespread groundwater impacts associated with historic human activity in the vicinity of the site (excluding groundwater impacts associated with the specific site).

This information will form the basis for determining whether or not the domestic consumption pathway is carried forward for further evaluation in the risk-based process.

Suitability for Use Determination: For groundwater to be considered a viable domestic water supply source, it must meet appropriate total dissolved solids (TDS) and yield criteria.

Total Dissolved Solids Criteria – Groundwater containing less than 10,000 mg/L total dissolved solids is considered a potential source of domestic consumption.

Yield Criteria – Groundwater zones capable of producing a minimum of 1/4 gallon per minute or 360 gallons per day on a sustained basis have sufficient yield to serve as a potential source of domestic consumption. The yield of a bedrock aquifer should be based on the measured or calculated production of a 6-inch drilled well that penetrates the lesser of either the full saturated thickness of the aquifer or the uppermost 200 feet of the saturated zone. The yield of a low-yield, unconsolidated (glacial drift or alluvial) aquifer should be based on the measured or calculated production of a 3-foot-diameter, augured or bored well that penetrates the lesser of either the entire saturated thickness of the aquifer or the uppermost 50 feet of the saturated zone. Refer to Appendix G, "A Method for Determining If a Water Bearing Unit Should Be Considered an Aquifer," for further guidance on determining whether a particular zone should be considered as a potential domestic water source.

Determination of Sole Source/Availability of Alternative Water Supplies: If the groundwater zone being considered is the only viable source of water at or in the vicinity of the site, then the remediating party must assume that future domestic use is reasonable. This conclusion is irrespective of TDS or yield considerations, and this zone must be evaluated if it is likely to be impacted by COCs from the site. Determining the availability of alternative water supplies should include consideration of other groundwater zones, municipal water supply systems, and surface water sources.

Reasonable Probability of Future Use Determination: The probability that a groundwater zone could be used as a future source of water for domestic consumption must be evaluated based on consideration of the following factors:

- Current groundwater use patterns in the vicinity of the site under evaluation,
- Suitability of use (TDS and yield criteria),
- Availability of alternative water supplies,
- AULs,
- Urban development considerations for sites in areas of intensive historic industrial or commercial activity, having groundwater zones in hydraulic communication with industrial or commercial surface activity, and located within metropolitan areas with a population of at least 70,000 in 1970, and
- Aquifer capacity limitations (ability to support a given density of production wells).

In metropolitan urban areas, common human activities often impact the uppermost-saturated zone. Due to these anthropogenic impacts, it may not be reasonable in some cases to consider the uppermost saturated zone as a water supply source. Examples include:

- Application of pesticides and fertilizers on household gardens,
- Leakage of waste from sewer pipes and septic tanks, and

- Infiltration of rain-dissolved chemicals that were present on the surface (oil from automobiles, etc.).

Probability of Impact Determination: If a groundwater zone has a reasonable probability of future use as a domestic water supply, the zone must be evaluated for the probability that the zone could be impacted by site COCs. The evaluation must consider the nature and extent of contamination at the site, site hydrogeology including the potential presence of karst features, contaminant fate and transport factors and mechanisms, and other pertinent variables. To evaluate potential site impacts to groundwater zones that could serve as future water supply sources, the potential impact must be evaluated at the nearest down-gradient location that could reasonably be considered for installation of a groundwater supply well. In the absence of durable AULs, the nearest location might be on the site itself.

6.7 VADOSE ZONE SOIL CHARACTERISTICS

Vadose zone soil is a medium through which COCs can migrate to groundwater and through which vapors can migrate upward to indoor and outdoor air. The following vadose zone parameters and their variability across the contaminated area significantly affect the movement of chemicals through vadose zone soil:

- Dry bulk density,
- Total porosity,
- Volumetric water content,
- Fractional organic carbon content,
- Thickness of vadose zone and depth to groundwater, and
- Thickness of capillary fringe.

The first four parameters - dry bulk density, porosity, water content, and fractional organic carbon content - are often collectively referred to as the soil geophysical or geotechnical parameters.

For Tier 1 evaluations, the department has assigned conservative default values to these parameters for three generic vadose zone soil types. As shown in Appendix E, Table E-4, these are:

- Soil type 1, representative of a sandy soil,
- Soil type 2, representative of a silty soil, and
- Soil type 3, representative of a clayey soil.

For Tier 2 and Tier 3 risk assessments, site-specific values based on data collected from the site or justified default parameters must be used.

If circumstances at a site are such that the geophysical properties cannot be determined because of sampling limitations, the remediating party must use appropriate conservative, justifiable literature values or values from samples collected in the field at nearby sites having very similar lithologic and geologic characteristics. If values cannot be found or do not exist, the remediating party should contact the department for further guidance.

Generally, collection of geophysical soil samples will require more than one boring or probe, depending on site conditions and recovery volumes. Ultimately the number of borings or probes necessary to obtain representative values of these parameters will be a site-specific decision of the driller and environmental consultant based on professional experience and judgment. The objective is to collect enough samples so that the results are representative of site-specific conditions. Fewer samples will be required at sites with relatively homogeneous vadose zone characteristics while more samples will be required if heterogeneous conditions exist.

In situations where undisturbed samples cannot practically be collected for the purposes of measuring dry bulk density, literature values may be used for this parameter. However disturbed samples must be collected and analyzed for fractional organic carbon, gravimetric water content, and particle density.

6.7.1 Thickness of Vadose Zone and Depth to Groundwater

The vadose zone is the uppermost layer of the earth and is conceptualized as a three-phase system consisting of solids, liquid and vapors. The thickness of the vadose zone can be determined based on information presented on boring logs and/or from measurements taken from monitoring wells or piezometers. It represents the distance from the ground surface to the depth at which the water table is encountered. For MRBCA evaluation, the capillary fringe thickness is not considered part of the vadose zone and is subtracted. Depth to groundwater is used to estimate vapor emissions from groundwater and to determine the vadose zone attenuation factor.

For sites where the water table fluctuates considerably, the available data must be evaluated to determine whether the fluctuations are seasonal or represent a consistent upward or downward regional trend. For sites with significant seasonal fluctuations, the average depth to groundwater and the average thickness of the vadose zone should be used in development of the overall conceptual site model and any related modeling efforts. Averages can be determined by groundwater level measurements obtained on at least a quarterly basis over one year. These averages should not; however, be used in the development of site-specific potentiometric maps, plans for well installation, or any other activities that require specific knowledge of fluctuations in groundwater flow direction(s). At sites with consistent, long-term (greater than one year) upward or downward water level trends that do not appear to represent seasonal fluctuations, the most recent data should be used to estimate the depth to groundwater and the thickness of the vadose zone.

At sites where the cleanup decision critically depends on the vadose zone thickness and/or depth to groundwater, and the depth to groundwater is known to fluctuate significantly, the department may request a sensitivity analysis. The analysis should be performed using different depths to groundwater and vadose zone thicknesses to assess the degree to which these parameters may affect the cleanup decision.

6.7.2 Dry Bulk Density

Dry bulk density is the dry weight of a soil sample divided by its field volume. An accurate measurement of dry bulk density requires determination of the dry weight and volume of an undisturbed sample. An undisturbed soil core sample may be collected using a Shelby™ tube, a thin-walled sampler, or an equivalent method. The sample must not be disturbed prior to laboratory analysis.

Dry bulk density is estimated using the American Society for Testing and Materials (ASTM) Method D2937, ***"Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method."*** At sites where multiple, widely differing soil types occur in the vadose zone, one sample must be collected from each distinct, predominant soil type. At such sites, the percentage of each soil type relative to the overall volume of the vadose zone should be considered in collecting samples and calculating bulk density. Where soil at a site is homogeneous or nearly so, a single sample for bulk density analysis may suffice.

6.7.3 Total Porosity

Total porosity is the ratio of the volume of voids to the volume of the soil sample. Many laboratories use dry bulk density and specific gravity of soil particles to calculate total porosity using the following:

$$n = 1 - \rho_b/\rho_s \qquad (6\text{-}1)$$

where,

n = porosity (cc/cc)
ρ_b = dry bulk density (g/cc)
ρ_s = specific gravity or particle density (g/cc).

Thus, specific gravity and soil dry bulk density are needed to determine total porosity.

The ***"Standard Test Method for Specific Gravity of Soil Solids by Water Pycnometer,"*** ASTM Method D854, may be used to determine specific gravity. If specific gravity or particle density is not available, 2.65 g/cc can be assumed for most mineral soils. However, the use of this value must be justified.

If a site-specific total porosity value cannot be determined, literature values consistent with the site lithology may be used, provided the source(s) of the value(s) is cited and justified. Effective porosity is the amount of void space available for fluid flow. Various studies have identified that even in very fine clays, such as lacustrine deposits, the effective porosity is practically the same as total porosity (Fetter, 2001). Where the total and effective porosities differ significantly, the department may require sensitivity analysis.

6.7.4 Volumetric Water Content/Moisture Content

Volumetric water content is the ratio of the volume of water to the volume of field or undisturbed soil. The ASTM Method D2216, **"Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soils and Rock by Mass,"** may be used to calculate this ratio. However, this is a gravimetric method that uses the mass of the sample, not the volume, to determine the ratio of water to soil. Therefore, to obtain the volumetric water content, the following conversion should be used:

$$\theta_{wv} = \theta_{wg} \times \frac{\rho_b}{\rho_l} \tag{6-2}$$

where,

θ_{wv} = volumetric water content (cc water/cc soil)
θ_{wg} = gravimetric water content, typically reported by the laboratory (g of water/g of soil)
ρ_b = dry bulk density (g of dry soil/cc of soil)
ρ_l = density of water (g/cc).

Multiple samples from across the site at varying depths should be analyzed for water content to estimate a representative water content value for the vadose zone. Each soil sample analyzed for one or more of the applicable COCs must also be analyzed for water content (at sites where multiple samples from multiple depths are analyzed for COCs on a dry weight basis, additional samples solely for analysis of water content may not be necessary). In addition, water content values representative of each of the lithologic units that comprise the vadose zone must be determined. Because all soil COC concentration data must be reported on a dry weight basis, the water content for each soil sample must be compiled, reported and used as needed in calculating target levels.

6.7.5 Fractional Organic Carbon Content in Soil

Fractional organic carbon content is the weight of organic carbon in the soil divided by the weight of the soil and is expressed either as a ratio or as a percent. Organic carbon content must be determined using soil samples <u>not impacted by petroleum or other anthropogenic chemicals.</u> Therefore, a soil boring away from the contaminated area but within a soil type that is the same as, or very similar to, that found at the site must be drilled to determine fractional organic carbon content. At a screening level, one method of determining if certain anthropogenic chemicals have impacted the sample is to take a PID reading.

Samples representative of the vadose zone must be collected for fractional organic carbon content analysis. At sites where the vadose zone consists of several different soil types, each predominant soil type must be sampled. Multiple aliquots of soil samples from the same lithologic unit may be collected vertically from a boring and horizontally from different borings and composited in the field to create a single sample. While creating a composite sample, care should be taken not to combine samples collected from different lithologic units. Surficial soils typically have the highest organic carbon content, and care should be taken not to bias the samples by collecting too much surficial soil.

For sites where subsurface soil types vary significantly, soil samples from the vadose and saturated zones should be collected at two or more boring or probe points that represent the differing soil types. As appropriate, the resulting fractional organic carbon content can then be averaged to establish a fractional organic carbon content for each media. If the individual data are representative of significantly different volumes of soil, a weighted average is preferable to the arithmetic average.

Fractional organic carbon content may be estimated using the Walkley Black Method (Page et al., 1982). However, some labs may not be familiar with this method. An alternative, though less preferred, method is ASTM Method D2974 ***(Standard Test Method for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils.*** This method measures the organic matter content of a sample. When using Method D2974, the result must be divided by 1.724 to get fractional organic carbon content. If the laboratory results are reported as a percent, fractional organic carbon content is obtained by dividing the results by 100.

6.7.6 Thickness of Capillary Fringe

The capillary fringe is the zone immediately above the saturated zone where capillary attraction causes upward movement of water molecules from the saturated zone into the soil above. This zone is distinct in that it has characteristics of both the vadose and saturated zones. In Tier 2 analysis, the thickness or height of the capillary fringe can be measured or an appropriately justified value used. Because accurate field measurement of the thickness of the capillary fringe can be difficult, literature values based on the soil type immediately above the water table may be used to assign a site-specific value for the capillary fringe thickness.

The thickness of the capillary fringe can significantly impact the risk-based concentrations in groundwater that are protective of indoor inhalation. Because this zone is not usually measured, the department may require that the remediating party estimate the most likely ranges of capillary zone thickness and depth to contamination and perform a sensitivity analysis. Most models used to perform this calculation assume the capillary fringe to be uncontaminated, which may not be accurate.

6.8 CHARACTERISTICS OF SATURATED ZONES

COCs may reach the water table by travelling vertically through the vadose zone.
Vertical migration can be expected in the following conditions:

- When the matrix porosity of the subsurface medium of interest is conducive to vertical migration,
- When a natural or induced downward vertical gradient exists between shallow and deeper saturated zones,
- When vertically oriented secondary porosity features are present, or
- When non-aqueous phase liquids (NAPLs) are present. Typically the vertical migration of light NAPLs (LNAPLs) will stop at the water table, whereas the dense NAPLs (DNAPLs) will continue to move vertically downwards through the saturated zone.

Saturated zone characteristics that determine the rate, magnitude and direction of migration of COCs in groundwater include:

- Horizontal and vertical hydraulic conductivity,

- Hydraulic gradients (magnitude in both horizontal and vertical direction),
- Residual mass in capillary fringe,
- Saturated zone soil geophysical characteristics (fractional organic carbon content, total and effective porosity, and bulk density),
- Occurrence and rate of biodegradation and retardation due to other factors, such as sorption due to soil mineral oxide content, and
- pH and redox potential especially at sites where the COCs include metals.

Of the characteristics mentioned above, the properties having the greatest influence on COC migration are hydraulic conductivity and hydraulic gradient.

Early in the process, various groundwater zones and the hydraulic inter-connection among them should have been identified. Qualitative and quantitative understanding of the above factors may be necessary for each of the zones.

When necessary, values of hydraulic conductivity, hydraulic gradient, effective porosity, and fractional organic carbon content must be used to estimate the theoretical advective migration velocity for the COCs in groundwater. The theoretical migration rate and extent of the groundwater plume should be compared with actual data to further validate the conceptual model.

6.8.1 Hydraulic Conductivity

Reliable estimates of site-specific hydraulic conductivity can be obtained by field methods such as pump tests or slug tests. In the absence of these tests, literature values corresponding to the type of soil in the saturated zone may be used. When a literature value is used, adequate reference and justification for the value based on consideration of all predominant soil types comprising the saturated zone must be provided. Hydraulic conductivity may also be estimated based on the grain size distribution of the porous formation.

The hydraulic conductivity can vary significantly in the horizontal and vertical directions. When referring to hydraulic conductivity always indicate whether reference is to horizontal or vertical direction. Horizontal hydraulic conductivity should be used to calculate the horizontal velocity of water and vertical hydraulic conductivity used to estimate the vertical velocity of water.

6.8.2 Hydraulic Gradient

The magnitude and direction of the hydraulic gradient is estimated by comparing water levels measured in monitoring wells across a site. A contour map must be prepared, either manually or using a computer program, using field measured water level data corrected to elevations relative to, preferably, sea level, or another arbitrary datum. These contour maps can be used to estimate both the direction and magnitude of the horizontal hydraulic gradient. When drawing the contour maps, care should be taken to ensure that measurements from monitoring wells screened in the same interval or hydrologic unit are used. For sites where wells are screened in multiple zones, a contour map for each zone must be developed (data from wells screened in different zones cannot be combined to draw one contour). For sites that have seasonal variation in hydraulic gradient or predominant flow direction, estimates of the average hydraulic gradient for each season and each flow direction can be used in modeling efforts. However, these estimates should not be used in the preparation of potentiometric maps or other activities where specific knowledge of the range of fluctuation in the groundwater flow direction is necessary (for example, locating and installing downgradient monitoring wells).

At sites with multiple groundwater zones, vertical gradients must also be determined via a comparison of water levels in adjacent wells screened at different intervals. The department will consider exceptions to this requirement on a site-specific basis.

6.8.3 Saturated Zone Soil Characteristics

The saturated zone soil characteristics include fractional organic carbon content, porosity, and dry bulk density. These parameters are required to estimate the extent of the contamination, including the retardation factor that "slows" the movement of chemicals within the saturated zone. These parameters are also necessary when estimating future concentrations or performing contaminant mass balance calculations using models that include a finite source or biodecay. Section 6.7 discusses the methods to measure these parameters.

6.8.4 Occurrence and Rate of Natural Attenuation/Biodegradation

The occurrence of monitored natural attenuation may be evaluated at a site. Measuring appropriate indicators (such as chemical concentrations, geo-chemical indicators, electron acceptors, microorganisms, or carbon dioxide) will be required only when monitored natural attenuation is proposed as the principal element of the risk management plan. Indicators can be broadly classified into three groups: primary, secondary and tertiary lines of evidence. Data collected under each line of evidence is used to qualitatively evaluate the occurrence of natural attenuation/biodegradation.

The primary line of evidence is developed by demonstrating, via the evaluation of COC concentrations in groundwater, that reductions in chemical concentration or mass are occurring at a site. The primary line of evidence is best determined by:

- Plotting concentrations of COCs as a function of distance along the plume center line,
- Plotting concentrations of COCs in each well as a function of time,
- Comparing COC concentration contour maps at various times,
- Performing contaminant mass balance calculations, and
- As appropriate, generating three-dimensional depictions of plumes and their migration over time.

In performing the above analysis, other factors that could influence the data, such as seasonal water level or flow direction fluctuations, should be taken into account.

A secondary line of evidence is necessary when the primary line of evidence is insufficient, or when such information is necessary to design a remedial system (for example, the addition of oxygen). The secondary line of evidence involves measuring geochemical indicators such as dissolved oxygen, dissolved nitrates, manganese, ferrous iron, sulfate and methane. These indicators must be measured in at least three wells located along the plume flow line. The wells must be located to represent conditions at:

- A background or upgradient location,
- An area within the plume near the source, and
- An area within the plume downgradient of the source.

Within the secondary line of evidence, measuring the degradation or breakdown products is another approach that can be used to demonstrate the occurrence of biodegradation. For example, natural degradation breaks down tetrachloroethylene (PCE) to trichloroethylene (TCE), vinyl chloride, and cis-1,2-dichloroethene (DCE). However, degradation products may be more toxic than the parent compound. Thus, the risk from degradation products also must be evaluated.

Developing a tertiary line of evidence involves performing microbiological studies to identify and quantify microorganisms within and near the plume. A tertiary line of evidence is used in very rare cases.

The development of secondary and tertiary lines of evidence is not always necessary. However, at most sites, groundwater sampling data should be plotted to evaluate temporal trends. These trends can be used to determine whether the plume is expanding, stable or decreasing. The department will require that the groundwater plume be stable or decreasing prior to issuing a Letter of Completion.

6.9 SURFACE WATER BODY CHARACTERISTICS

The following data must be collected for a surface water body that may be impacted by site-related COCs:

- Distance to the surface water body,
- Likely location where COCs from the site would discharge into a surface water body,
- Flow direction and depth of any groundwater contamination plume(s) in relation to the water body,
- Lake or stream classification as found in 10 CSR 20-7.031, Table G and Table H respectively. Definitions for classifications can be found in 10 CSR 20-7.031(1)(F),
- Lake or pond acreage or stream 7Q10 flow rate,
- Determination of the beneficial uses of the lake or stream as found in 10 CSR 20-7.031, Table G and Table H respectively, and
- Water quality criteria based upon the beneficial uses of the lake or stream as found in 10 CSR 20-7.031, Table A. If a water quality criterion for a COC is not available, contact the department project manager. If necessary, the project manager can then coordinate with the Water Protection Program (WPP) for further guidance.

In addition, refer to Appendix E for information about developing soil and groundwater target levels that protect surface water beneficial uses.

6.10 DELINEATION OF IMPACTS

MRBCA evaluation requires the collection of sufficient data to delineate the impacts in various contaminated media, as discussed below.

6.10.1 Delineation of Impacts in Soil and Groundwater

Prior to the performance of a risk assessment, the remediating party must review the available data and determine if data of sufficient quality and quantity are available to delineate the extent of impacts in soil and groundwater. A variety of data are necessary, such as land use, water use, any activity or use limitations, site geology and hydrogeology, and analytical data for each contaminated media. The horizontal and vertical extent of soil and groundwater contamination must be delineated to the extent necessary to assess potential exposures to receptors and impacts to surface water bodies both on- and off-site.

The key issue related to the delineation of impacts is the concentration levels to which impacts are defined. Several alternatives are available. Examples include but are not limited to: background levels, drinking water levels, generic screening levels, site-specific screening levels, or non-detect levels. The MRBCA guidance does not explicitly specify one-size-fits-all delineation concentrations for environmental media; instead, it uses "performance based" delineation criteria, as explained below.

Lateral and vertical impacts in soil and groundwater must be delineated to the extent required to determine:

- Potential routes of exposure by human and environmental receptors under current and future conditions, <u>and</u>
- The extent of impacts above risk-based levels for corresponding potential routes of exposure.

For example,

- Delineation may be to non-residential levels on site at non-residential facilities, but if the plume extends off-site and surrounding land uses are residential, then delineation would be to residential levels,
- Delineate soil to the lower of levels protective of indoor inhalation or domestic use of groundwater target levels, depending on the complete routes of exposure, or
- Delineate to media transfer screening levels if volatile compounds are beneath existing buildings or planned future buildings would be located over contaminated areas.

The above use of performance criteria presents a dilemma in that the contaminated media must be sufficiently delineated to evaluate the risk at a site; however, risks cannot be accurately estimated until the site has been delineated. If AULs or engineering controls may be used as a component of the final remedy, delineation efforts will need to define areas over which these controls will be placed.

Thus, an iterative approach to delineation may be necessary unless the remediating party decides to delineate the site to very conservative concentrations such as background or non-detectable levels. If these very conservative delineation standards are not used, the following iterative approach is described for use. This approach may be more cost effective than delineating to very conservative levels, but it requires additional professional judgment and up front preparation. At sites where it is clear that active remediation is necessary, the remediating party may proceed with interim remedial measures and subsequently use confirmatory samples to delineate the plume. Thus, issues associated with plume delineation would not delay the implementation of remedial activities.

1. Prior to performing the site work, develop a preliminary conceptual site model, including the exposure model. The exposure model must consider receptors on site and on adjacent properties that may be contaminated. This will require a determination of whether the domestic use of groundwater is or could be a complete pathway.

2. Based on the complete exposure pathways for soil and groundwater and the type of vadose zone soil, identify the applicable generic Tier 1 screening levels from the tables in Appendix B. In Tier 1 delineation, when cumulative site-wide risk appears to increase risk beyond acceptable levels, then the project manager should discuss this problem with the remediating party. At sites where it is clear that a Tier 2 risk assessment will be necessary and enough information is available about the site, it would be reasonable at this time for the remediating party to develop preliminary Tier 2 target levels. In developing any risk-based target levels, cumulative site-wide risk must be addressed.

3. After the delineation levels for each COC have been established, the following field activities should be conducted:
   - Groundwater data from a direct push investigation may be used to determine the extent of impact to the delineation levels, followed by the installation of monitoring wells. The number and location of monitoring wells is a very site-specific professional decision. Often, delineation will require multiple field mobilizations. For sites where sufficient groundwater data from monitoring wells indicates a declining plume, data from a direct push investigation could be used to delineate the downgradient extent of the plume. If used, direct push investigations should be conducted downgradient of the site source/release area until data indicates levels at or below the delineation level.
   - For sites where the available data indicates that the plume may be migrating, the remediating party must conduct sufficient investigations to determine the extent and rate of migration. It may be more cost effective to conduct a direct push investigation followed by the installation of a permanent delineation monitoring well(s). Wells must be monitored at a frequency and for a period of time sufficient to clearly demonstrate that the plume is declining and that COC concentrations in the downgradient wells are below the delineation levels.
   - Upon preliminary completion of the site characterization, a check should be made to confirm that the assumptions used in the initial conceptual site model were accurate and that the delineation levels are appropriate.
   - For delineation of soil impacts, borings should be installed at increasing distances

from the source area until the generic delineation levels are reached.

Chemical fate and transport modeling may be used as appropriate to aid in the placement of monitoring wells.

6.10.2 Delineation of Impacts in Other Media

In addition to the delineation of soil and groundwater impacts, impacts to other media, (for example, surface water, sediments, and air) must be evaluated. The number of samples, sample locations, delineation levels, and sampling methodologies will be based on site-specific considerations; hence the remediating party must receive the department's approval for the work plan prior to conducting fieldwork. For surface water and sediment sampling, the work plan must contain a strategy to determine background levels, location and concentration of site-related discharges to the surface water, and the extent of the impacts. If air concentrations are to be measured, the work plan must contain a strategy to determine ambient background levels.

Because the delineation process may be iterative, as part of the work plan report, the department will require documentation supported by site-specific data to confirm that the impacts have been delineated to the final risk-based target levels in all media.

6.11 ECOLOGICAL RISK ASSESSMENT

In the MRBCA process, site remediation must be protective of both human health and ecological receptors before a Letter of Completion can be issued. Ecological protection includes all non-human organisms and their habitats (ecological receptors). Therefore, exposure to ecological receptors must be considered and evaluated.

Section 5.4 discusses the process for determining if a COC may impact an ecological receptor at the Default Target Level. Within the tiered MRBCA process, ecological risk assessment has three levels:

- Level 1 is a qualitative screening evaluation comprised of Checklists A and B,
- Level 2 requires comparison of site-specific levels with applicable ecological standards, readily available in literature, and
- Level 3 allows for a site-specific evaluation.

A Level 2 and /or Level 3 evaluation is necessary only if ecological concerns continue to persist beyond the Level 1 evaluation.

6.11.1 Level 1 Ecological Risk Assessment

A Level 1 ecological assessment must be performed at every Tier 1, 2, and 3 site to identify whether any ecological receptors or habitat exist at, adjacent to, or near the site. The evaluation, beginning with Ecological Risk Assessment Checklist A (Appendix F), consists of seven questions. This checklist is a qualitative evaluation that can be completed by an experienced environmental professional who is not necessarily a trained biologist or ecologist. The checklist is designed such that, if the answer to all the questions is negative, no further ecological evaluation is necessary.

A positive answer to any one of the questions in Checklist A implies that a receptor or a habitat exists on or near the site and further evaluation is required. Therefore, a second checklist of seven questions, Ecological Risk Assessment Checklist B, must then be completed. The second checklist determines if any pathways are complete for any of the receptor(s) identified in Checklist A. If the answer to all questions is negative, the conclusion is that, even though a receptor exists on or near the site, a complete pathway to the receptor(s) does not exist and, therefore, there are no ecological concerns at the site. If the answer to one or more of the seven questions is positive, a Level 2 ecological risk assessment may be necessary to determine whether contamination at the site poses an unacceptable risk to ecological receptors.

6.11.2 Level 2 Ecological Risk Assessment

In a Level 2 ecological risk assessment, site-specific COC concentrations that may reach an environmental receptor are compared to Missouri's Water Quality Criteria or literature values when standards are not available. For site COCs listed in Table 5-1, the groundwater values listed are protective of aquatic ecological species. Examples of additional sources for these values include the following:

- Missouri's Water Quality Standards, 10 CSR 20-7.031, Table A – Criteria for Designated Uses. (Available at the Missouri Secretary of State's website http://www.sos.mo.gov/adrules/csr/current/10csr/10c20-7a.pdf),
- Ecotox Thresholds (ETs) as presented in ECO Update, US EPA, Office of Solid Waste and Emergency Response. Publication 9354.0-12FSI, EPA 540/F-95/038, PB95-963324. January 1996. Office of Emergency and Remedial Response Intermittent Bulletin Volume 3, Number 2,
- ORNL Values as presented in Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. ES/R/Tm-96/R2. Suter II and C.L. Tsao. June,
- EPA Water Quality Standards – http://www.epa.gov/waterscience/standards/,
- TOXNET (National Institute of Health) – http://toxnet.nlm.nih.gov/index.html, and
- National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Table (SQuiRTS) which may be found at http://response.restoration.noaa.gov/cpr/sediment/squirt/squirt.html.

If the comparison of representative, site-specific soil, groundwater, surface water or sediment values indicates that applicable values are exceeded, the remediating party may perform a Level 3 ecological risk assessment or use the applicable water quality criteria or literature values as cleanup goals. If the latter option is chosen, then at least one element of the Risk Management Plan must address remediation goals to protect ecological species.

6.11.3 Level 3 Ecological Risk Assessment

A Level 3 ecological risk assessment will include a detailed site-specific evaluation as per current USEPA guidance on performing risk assessment (for instance, ***EPA's April 1998, Guidelines for Ecological Risk Assessment, EPA/630/R-95/002F***). A Level 3 ecological risk assessment will require the development of a site-specific, detailed work plan and approval by the department prior to its implementation. As above, if a site-specific analysis determines that the risk to ecological species is still unacceptable, then at least one element of the risk management plan must address managing the risk to ecological species.

6.12 DISTRIBUTION OF CHEMICALS OF CONCERN IN SOIL

The objective of soil characterization is to (i) delineate the extent of site-related COCs to identify the exposure domains for each combination of receptor-pathway-complete route of exposure, and (ii) estimate maximum and representative concentrations for each area of impact/exposure domain.

As noted in 6.4.2, the MRBCA program distinguishes between surficial soil and subsurface soil. A key difference between surface and subsurface soil is that, for surficial soil, the direct contact pathway (ingestion, dermal contact and outdoor inhalation of vapors and particulates) is considered complete for both the residential and non-residential receptors. For the subsurface soil, this pathway is considered incomplete except for the construction worker who may be involved in excavation activities below the surficial zone and hence may come in direct contact with subsurface soil. Thus, for the construction worker, no distinction is made between the surface and subsurface soil. In Tier 3 and based on site-specific exposure conditions, the depth of surface soil may be modified.

Because of the differences in exposure pathways for surface and subsurface soils, an adequate number of soil samples from each zone must be collected to meet the soil characterization objectives. Surficial soil (as well as subsurface soil) may include fill material - the distinction between surface and subsurface soil is one of depth rather than composition.

As discussed in Section 6.10.1, surficial and subsurface soil impacts should be delineated to the extent necessary to allow for assessment of risks to human health, public welfare and the environment. Delineation criteria are not a hard and fast number, but would depend on a number of site-specific factors. Typically the most conservative delineation criteria would be the lower of the levels protective of residential land use, background levels, or levels that could result in unacceptable contaminant transfers from soil to other media such as groundwater or air.

The number and locations of soil borings necessary to adequately delineate a site will vary from site to site depending on various factors; size of site, distribution of COCs, site hydrology and stratigraphy, exposure model, etc.

6.12.1 Logging of Soil and Groundwater Monitoring Well Boreholes

A qualified professional - a Registered Geologist (R.G.) or Professional Engineer (P.E.) registered in Missouri - must log each soil boring to indicate depths correlating with changes in lithology (with lithologic descriptions), occurrence of groundwater, total depth, visual and olfactory observations, and other pertinent data such as a soil vapor screening reading. When a monitoring well is installed, as-built diagrams with depth to groundwater indicated must be submitted for each well. A continuous soil profile from soil borings should be developed with detailed lithologic descriptions. Particular emphasis should be placed on characteristics that may control chemical migration and distribution such as zones of higher or lower permeability, changes in lithology, correlation between soil vapor concentrations and different lithologic zones, obvious areas of soil discoloration, organic content, fractures, and other lithologic characteristics.

All boreholes and probes greater than 10 feet in depth must be abandoned in accordance with 10 CSR 23-4.080(6).

6.13 DISTRIBUTION OF CHEMICALS OF CONCERN IN GROUNDWATER

An adequate number of groundwater samples must be collected to:

1. Delineate the horizontal and vertical extent of dissolved groundwater COC plumes and non-aqueous phase liquids (NAPLs), and to identify the exposure domain for each receptor, pathway and route of exposure combination,
2. Allow calculation of representative COC concentrations for each exposure domain, and
3. Determine the status of the plume (increasing, stable or declining).

6.13.1 Delineation of Groundwater Impacts

The delineation criteria for groundwater depend on whether the groundwater pathway for ingestion is complete or incomplete based on consideration of current and potential future domestic use of the groundwater.

Where the domestic use of groundwater pathway is complete, delineation criteria will be the lower of the following four criteria:

1. The MCLs (in the absence of MCLs, risk-based concentrations that assume ingestion of groundwater and inhalation of vapors due to indoor water use),
2. Land use-dependent concentrations protective of indoor inhalation,
3. Concentrations for the protection of ecological receptors (when present), or
4. Non-domestic uses of groundwater when present.

Where the domestic use of groundwater pathway is determined to be incomplete, the delineation criteria will be based on other potentially complete pathways. Examples are: protection of indoor air due to volatilization of contaminants from the groundwater, exposures that may be encountered by subsurface construction workers, or the discharge of contaminated groundwater to surface water.

Tables in Appendix B provide:

- MCLs or risk-based groundwater concentrations protective of ingestion and inhalation due to indoor water use, and
- Risk-based groundwater concentrations protective of indoor inhalation for resident and

non-residential worker.

Table 5-1 provides water quality criteria for chemicals for which the ecological protection values are lower than the MCLs or where no equivalent groundwater criteria exist in Missouri's Water Quality Standards.

6.13.2 Determination of Plume Stability

To assess plume stability, groundwater monitoring must be conducted for a period of time sufficient to show a reliably consistent trend in contaminant concentrations. Sampling and analysis of groundwater must be performed at a frequency and for parameters that are appropriate for site-specific conditions and are sufficient to enable assessment of contaminant trends, natural attenuation rates and seasonal or temporal variations in groundwater quality. Once cleanup levels are achieved, groundwater monitoring must continue for a period of time sufficient to ensure that residual subsurface contamination does not result in recontamination of groundwater above applicable MCLs or levels protective of other pathways, such as migration to surface water or indoor inhalation.

Groundwater monitoring for the purpose of evaluating plume stability must be conducted under a work plan approved by the department. Depending on site-specific data, statistical, graphical or other techniques may be used to demonstrate plume stability.

6.13.3 Groundwater Sampling

If groundwater has been contaminated by COCs, direct push sampling methods or temporary sampling points may be used to screen for groundwater contamination and to assist in determining the optimal location of monitoring wells. Monitoring wells must be installed in accordance with Missouri regulations, 10 CSR 23-4.010 through 10 CSR 23-4.080 and the following guidelines:

- An adequate number of monitoring wells must be installed to sufficiently delineate the horizontal and vertical extent of the dissolved and non-aqueous phase groundwater plume and the direction of groundwater flow.
- A sufficient number of monitoring wells must be installed to fully define the groundwater plume to levels protective of applicable exposure pathways.
- Well placement and design must consider the concentration of chemicals in the source area, the possible occurrence of both dense and light NAPLs at the site, presence of multiple water bearing zones, and groundwater flow direction.
- Well casing and screen materials must be compatible with the COCs to be monitored.
- Wells must be properly developed and the water level must be measured after installation.
- A land surveyor is the best qualified to conduct a site survey to establish well elevations and, by that, groundwater elevations. Accuracy should generally be to within plus or minus 0.01 foot relative to an established national geodetic vertical datum (NGVD) or some appropriate benchmark. Based on the groundwater elevations, groundwater flow

direction and gradient must be determined and plotted on a site map.

- Appropriate geographic coordinates must be identified and documented.

Groundwater samples must be collected in accordance with the approved work plan.

6.14 DISTRIBUTION OF CHEMICALS OF CONCERN IN SOIL VAPOR

For sites where soil or groundwater concentrations result in the exceedance of Tier 1 risk levels for the vapor migration to indoor air pathway, soil vapor monitoring may be conducted. For further details, refer to Appendix H. Soil vapor sampling methodology would be included in a data collection work plan.

6.15 DISTRIBUTION OF CHEMICALS OF CONCERN IN SEDIMENTS AND SURFACE WATER BODIES

When site investigation data or modeling shows or suggests that COCs may have migrated to a surface water body, surface water samples should be collected. Sampling must consider the representativeness of the samples with regard to the flow conditions. Water samples must be collected both upstream and downstream of each area where a discharge of contaminated groundwater is suspected.

If site investigation data shows or suggests that contaminated groundwater is discharging to surface water, sediment samples must be collected. The remediating party must compare the sediment sample data with sediment standards that are protective of human health and ecological receptors that can be obtained from literature or develop site-specific levels. The development of site-specific sediment standards would be considered a Tier 3 activity and would require a pre-approved work plan.

6.16 COLLECTION AND ANALYSES OF ENVIRONMENTAL SAMPLES

The remediating party must exercise extreme care in the collection of environmental samples. This guidance focuses on data necessary for the MRBCA evaluation; it does not identify specific field sampling techniques and laboratory analytical methods to be used. The remediating party must collect all environmental samples using appropriate methods and minimize chemical losses during sampling.

The remediating party must document the details of collecting and analyzing the samples in the work plan and obtain the department's approval prior to collecting the data. Failure to do so may result in the collection of data not acceptable for MRBCA evaluation and additional sampling may be required.

6.17 INFORMATION SOURCES FOR DATA COLLECTION

The above sections present an overview of the data needed to develop the conceptual site model, and delineate releases for preparation of a risk-based evaluation. Whereas it is relatively easy to determine the categories of data required, it requires considerable judgment, knowledge and experience to determine the location and number of samples to be collected and analyzed and the sampling and analytical methodologies to be used in data collection.

The following selected references can assist the user in developing a comprehensive work plan, identifying data gaps, and planning and implementing fieldwork.

- Missouri Department of Natural Resources, Quality Management Plan for Missouri Department of Natural Resources: Air and Land Protection Division, Geological Survey and Resource Assessment Division, and Water Protection and Soil Conservation Division (Refer to most current version).

- EPA, 1998. Guidance for Data Quality Assessment: Practical Methods for Data Analysis, Office of Research and Development, EPA/600/R-96/084, Washington, D.C.

- EPA, 1997. Expedited Site Assessment Tools for Underground Storage Tank Sites, EPA/510B-97-001, Office of Solid Waste and Emergency Response, Washington, D.C.

- ASTM, 1995. Standard Guide for Developing Conceptual Site Models for Contaminated Sites: E 1689-95.

- EPA, 1994. Guidance for the Data Quality Objectives Process, Office of Research and Development, EPA/600/R-96/055, Washington, D.C.

- EPA, 1993. Data Quality Objectives Process for Superfund, Interim Final Guidance, EPA/540-R-93-071, Office of Solid Waste and Emergency Response, Washington, D.C.

- EPA, 1992. Guidance for Data Usability in Risk Assessment, Part A, Office of Solid Waste and Emergency Response, 92857-09A, Office of Emergency and Remedial Response, Washington, D.C.

- EPA, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, OSWER-9335.3-01, Office of Solid Waste and Emergency Response, Washington, D.C.

- EPA, 1986. RCRA Groundwater Monitoring Technical Enforcement Guidance Document Draft, OSWER-9950.1, Office of Solid Waste and Emergency Response, Washington, D.C.

7.1 INTRODUCTION

During site investigations, a considerable quantity of analytical data may be collected. Each sample of impacted media (soil, groundwater, air, surface water and sediment) may have been analyzed for hundreds of chemicals. This is often an artifact of the sampling protocols that analyze for and report a large suite of chemicals, not just the chemicals that are site related. Some chemicals may have been detected; others not. Further, all of the detected chemicals may not be site-related, but instead exist in the natural environment. Or, they may pose a negligible risk compared to other chemicals. Therefore, it may be cost-effective to eliminate some of these chemicals early in the MRBCA process and not include them in the tiered risk evaluation process. Early elimination of some chemicals can focus the tiered evaluation on the chemicals that pose the most risk and therefore will drive the site cleanup.

This section presents several steps to eliminate some chemicals and focus the risk assessment on the chemicals of concern (COCs) that contribute to the total risk at a site. Figure 7-1 shows the process of eliminating chemicals. Depending on site-specific conditions, all the steps identified below may not be necessary at each site. Further, additional methods not discussed below may be used with approval from the department.

7.2 COMPILATION OF ALL DATA BY QUALITY

Typically, analytical data at a site is collected during the course of several investigations with the data included in several different reports. Thus, an important key step in managing and understanding site data is to know when the various data were collected, the analytical method used, and the quality assurance/quality control (QA/QC) criteria that were applied. The data should then be carefully evaluated to determine if the data should be eliminated, used qualitatively, or used quantitatively in the risk assessment.

Examples of data that may be eliminated include:

- Data analyzed using an outdated analytical method or a wrong and unproven method (for example, TPH concentrations using USEPA Method 418.1),
- Data that is not adequately supported by corresponding QA/QC data/measures,
- Old data that is not considered representative of current conditions, or
- Data collected prior to any remediation at the site.

Old or field screening data may be used for qualitative analysis to examine trends in the data. The elimination of any data by these or similar criteria is based on the condition that higher quality, newer and more representative data is available. Data should not be eliminated unless better information is available or the data is clearly unusable for any purpose.

Any data that is not used in the quantitative risk assessment must be clearly identified and the reason for its elimination determined. This information must be clearly documented in the Tiered Risk Assessment Report.

7.3 PARTITIONING OF DATA INTO CHEMICALS DETECTED AND CHEMICALS NOT DETECTED

The data considered usable for risk assessment should be partitioned into data for each media of concern, for example, surficial soil, subsurface soil, soil within the depth of construction, shallow groundwater, surface water, etc. Within each media divide the samples into two lists.

- List 1 should contain all chemicals that were analyzed for but were not positively detected in any of the samples.
- List 2 should contain data for all the samples that had at least one detected value.

7.4 CONSIDERATION OF CHEMICALS NOT DETECTED IN ANY SAMPLE

With List 1 (defined above), analytes that were not positively detected in any of the samples may be eliminated from further consideration if:

- The detection limits meet the QA/QC requirements, or
- All detection limits for a particular chemical are less than the appropriate Tier 1 risk-based target levels.

If a chemical was never detected positively in any sample due to the analytical method used, but it may be site related, the media might need to be sampled again using an alternative laboratory method.

7.5 CONSIDERATION OF CHEMICALS WITH POSITIVELY DETECTED VALUES

The second list of analytes with at least one detected value, List 2, should be carefully examined. Chemicals may be eliminated with department approval based on the following considerations:

1. The maximum concentration is less than the default target levels.
2. If the chemical appears to be a tentatively identified compound and the historical site review indicates that it was not used at the site nor migrated from a nearby site
3. If a statistically sufficient number of samples were collected per media including source areas and the analyte was detected in less than 5 per cent of the samples by media or source area (assuming that more than one sample was collected from the "source area").
4. The concentration of chemicals detected on site is the same or less than the concentration in background samples based on site-specific measurements. In the absence of these and with the department's concurrence, background concentrations from published sources may be used.
5. The analyte is either a laboratory or sampling artifact. This would be particularly true if the chemical was also persistently detected in the QA/QC samples associated with the corresponding media of concern. (For example, if acetone is present in the groundwater but is attributed to a laboratory problem, that conclusion must be justified by acetone showing up in the associated QA/QC samples for groundwater, not in the soil or some

other media. Elimination of COCs from further consideration due to laboratory artifacts or common laboratory contaminants should be supported by site-specific QA/QC information.)

7.6 ELIMINATION USING TOXICITY SCREEN

If the above screening process results in more than 30 chemicals, additional chemicals may be eliminated by the use of the toxicity screen (USEPA, 1989). The objective of this screening procedure is to identify and possibly eliminate chemicals that are likely to contribute less than 1 to 5 per cent of the total risk. Step-by-step procedures to estimate the contribution to risk are discussed below.

Step 1: Identify the maximum concentration of the chemical in each media.

Step 2: Select the toxicity value(s), i.e., the reference dose and the slope factor for the chemical from Appendix E. For chemicals that have different toxicity values for various routes of exposure, use the most "toxic" value, i.e., highest slope factor and smallest reference dose.

Step 3: Estimate the carcinogenic and non-carcinogenic toxicity score by multiplying the concentration with the slope factor, and by dividing the concentration with the reference dose, respectively.

Step 4: Estimate the site score by adding the toxicity score for each chemical and each media. A separate site score will be calculated for carcinogenic and non-carcinogenic effects.

Step 5: Estimate the percent contribution of each chemical to the site score and eliminate chemicals that have a very low score relative to the other chemicals. In general, chemicals with a percent toxicity score of less than 1 per cent may be readily eliminated. In certain cases, depending on the distribution of the toxicity scores, chemicals with the toxicity score of up to 5 per cent may be eliminated. Tables 7-1 and 7-2 are sample spreadsheets demonstrating the above procedure.

The elimination of any chemicals as well as the rationale used must be clearly documented. Upon completion of the Tier 1, Tier 2, or Tier 3 evaluation, it may be necessary to re-visit the chemicals that were eliminated, especially when using the toxicity screen, and make a determination whether their inclusion may have resulted in an unacceptable risk. In some cases the cleanup criteria may have to be adjusted downwards to account for the risk that these chemicals would contribute.

If the maximum soil or groundwater concentrations exceed the default target levels (DTLs), the remediating party may choose to complete a Tier 1 Risk Assessment in lieu of cleanup to the DTLs. As shown in Table 2-1, a Tier 1 Assessment may use the concept of representative concentrations as opposed to maximum concentrations. An Ecological Risk Assessment is required and Activity and Use Limitations (AULs) may be needed.

After sufficient quality and quantity of data (Section 6.0) has been collected and the COCs identified, a Tier 1 risk assessment can begin. To complete a Tier 1 risk assessment, the following steps must be completed:

1. Compile data and identify data gaps,
2. Develop exposure model,
3. If necessary, collect data to fill data gaps,
4. Calculate media and pathway-specific representative concentrations for chemicals of concern (COCs),
5. Select relevant Tier 1 risk-based target levels from lookup tables and compare with site concentrations,
6. If necessary, calculate cumulative site-wide risk and compare with acceptable risk,
7. Evaluate the next course of action, and
8. Document Tier 1 risk assessment and recommendations.

The Ecological Risk Assessment levels used to evaluate the site are independent of the human-health-based tier assessments. In other words, a Tier 1 risk assessment could include a Level 3 Ecological Risk Assessment. Conversely, a Tier 3 Risk Assessment could be completed in conjunction with a Level 1 Ecological Risk Assessment.

Details of each step are presented below.

8.1 STEP 1: COMPILE DATA AND IDENTIFY DATA GAPS

The objective of this step is to compile available relevant data, evaluate the data, and identify any data gaps. This step and Step 2 (development of an exposure model) should be completed simultaneously because the development of an exposure model may also help identify data gaps.

Because a Tier 1 risk assessment can be performed with minimal data, additional data may not be necessary at sites that have been characterized prior to the effective date of this guidance. However, examples of Tier 1 data gaps include:

- Lack of a current land use map,
- Lack of soil or groundwater COC concentrations representative of current conditions (for example, soil or groundwater COC data is too old or not representative of recent releases or the exposure domain),
- Insufficient delineation of contamination at the site,

- Lack of soil and groundwater data for certain COCs, and
- Inadequate determination of complete pathway for domestic use of groundwater.

To ensure that all data gaps have been identified, the remediating party should refer to Section 6.0 and the references contained in that section.

8.2 STEP 2: DEVELOP EXPOSURE MODEL

This step is necessary to identify exposure pathways at a site that are currently complete or that are reasonably likely to become complete in the future. The presence of exposure pathways and receptors is dependent on current and anticipated future use of the site. If contamination could potentially migrate off site, any affected properties must also be considered when developing the exposure model.

Pathways are determined by considering the locations of the point and size of release, the extent of contamination, the location of receptors, and the media through which chemicals migrate from the location of the release to the receptors. Prior to determining exposure pathways, sufficient site characterization must be conducted such that the horizontal and vertical extent of COCs in soil and groundwater has been determined to appropriate risk-based levels. Otherwise, pathways of concern may be excluded or pathways not of concern (due to their location relative to the location of soil or groundwater contamination) may be erroneously included in the evaluation. Delineation of impacts may be an iterative process as discussed in Section 6.10.

Thus, in Step 2, an exposure model is developed to identify:
1. All complete routes of exposure for current and future land use,
2. The exposure domain for each complete route of exposure, and
3. The point of exposure for each route of exposure.

Determination of the exposure domain(s), as defined in Section 8.4 and discussed further in Appendix C, for each complete or potentially complete pathway is necessary because the data collected within an exposure domain only will be used to estimate the representative concentration.

As part of this step, the exposure model should be clearly documented. Specifically, the remediating party must:
1. Document the pathways that are complete under current and future conditions,
2. Explain the rationale for pathway decisions, both complete and incomplete,
3. Identify the monitoring locations within the exposure domains identified above that will be used to estimate representative chemical concentrations for each pathway.

Under the second step above, the following is an example of an appropriate justification for an incomplete pathway for vapor intrusion under a building: The COC's are non-volatile chemicals, such as metals (except for mercury).

8.3 STEP 3: COLLECT DATA TO FILL DATA GAPS

Step 3 is necessary only if data gaps are identified in Step 1. If additional environmental measurements or testing is needed at this step, the remediating party must develop an additional sampling and analysis plan. Refer to Section 6.0 for information on data collection activities. If additional soil or groundwater data are necessary, soil geotechnical parameters, typically required for a Tier 2 risk assessment, may also be collected at this time because doing so may avoid a second field mobilization and hence would be more cost-effective.

After completion of this step in a timely manner, in conformance with an approved work plan, and with appropriate documentation of the fieldwork, the remediating party can proceed to Step 4. Depending on the specifics of the data gaps, it may not be necessary to submit a separate data collection work plan to the department. Instead, it may be submitted as an attachment to the Tier 1 Risk Assessment Report.

8.4 STEP 4: CALCULATE REPRESENTATIVE CONCENTRATIONS

Using the information from Steps 1 through 3, the remediating party must calculate representative chemical concentrations for each exposure domain, as discussed in Appendix B. "Exposure domain" refers to the portion of an impacted area/volume of media that contributes to the risk for a particular pathway. The need to calculate representative concentrations may be avoided by initially using the maximum media-specific concentrations for each pathway as the representative concentration. If the risk calculated with the use of the maximum concentrations (which are the most conservative numbers) meet the Tier 1 risk-based target levels, calculation of representative concentrations is not necessary.

Depending on site conditions, multiple representative concentrations (one for each exposure domain) may have to be calculated. For example, in the following three complete exposure pathways at the same site, the exposure domains will likely be different and hence the representative concentrations may differ:

1. Subsurface soil concentration for the indoor inhalation route of exposure for the on-site non-residential worker,
2. Surficial soil concentration for direct contact pathway for the on-site non-residential worker, and
3. Soil concentration for the on-site construction worker.

At certain sites, multiple representative concentrations may be necessary for the same route of exposure. For example, if a groundwater plume has migrated below a commercial building and a residential building, representative groundwater concentrations for the volatilization from groundwater to indoor air could be different for the residential and the non-residential receptors.

If a Level 2 Ecological Risk Assessment (as described in Section 6.11) is necessary, representative concentrations for the relevant media and relevant COCs may also be calculated.

8.5 STEP 5: SELECT RELEVANT TIER 1 LEVELS

In Step 5, generic Tier 1 risk-based target levels for each chemical, each receptor, and each route of exposure must be selected from Appendix B. Tier 1 risk-based target levels have been developed for three different vadose zone soil types. As shown in Appendix E, Table E-4, these include (i) soil type 1 representative of a sandy soil, (ii) soil type 2 representative of a silty soil, and (iii) soil type 3 representative of a clayey soil. For residential land use, Tier 1 values must be selected for three receptors: child, adult, and age-adjusted individual.

The Tier 1 risk-based target levels for each complete route of exposure and each COC must be compared with the appropriate representative concentration.

If it is necessary to perform a Level 2 Ecological Risk Assessment, the remediating party must identify published concentrations protective of ecological receptors and compare the maximum or representative concentrations with these values.

8.6 ANALYTICAL DETECTION LIMITS

During the course of demonstrating that target concentrations have been achieved, the analytical detection limit for certain COCs in environmental media may be higher (sometimes by orders of magnitude) than the corresponding target cleanup level (e.g., DTL, Tier I) for that chemical. This happens because the concentrations of chemicals that can be positively detected are limited by the capabilities of the analytical method used.

For information purposes, the following have been identified in Appendix B:

- COCs with DTLs or Tier 1 RBTLs lower than the detection limit or Practical Quantitation Limit (PQL) of current analytical methods, and
- COCs that do not have a standard method listed in SW-846.

This discussion identifies the approaches that may be used in instances where the target cleanup level for a particular COC(s) cannot be achieved using standard analytical methods. In such circumstances, the following approaches may be useful:

1. Check the data to confirm that the standard detection limits are indeed higher than the DTLs or RBTLs and that no errors were committed (for example, transposing numbers, misplacing a decimal point, or unit conversion),
2. With department approval, use alternative analytical methods that achieve lower detection limits than the DTLs or RBTLs.
3. Perform a focused Tier 2 or Tier 3 Risk Assessment to determine if the levels that can be analytically quantified are protective of human health and the environment given the complete and/or potentially complete exposure pathways. This approach could involve the use of a detection-based scenario (i.e., using the maximum detection limit of the COCs) in conjunction with alternate site-specific exposure factors to calculate if the risk is acceptable.
4. Develop areal contaminant trends that can then be used to extrapolate contaminant extent to the target level(s) followed by calculation of average concentrations based on those

extrapolations. Fate and transport models used in conjunction with "above analytical detection limit results" for certain problematic chemicals could also be used to extrapolate contaminant extent, thereby facilitating calculation of average concentrations for comparison to target cleanup levels.

These approaches may be most useful where short-term decisions regarding the completion of cleanup are desired. Other approaches may be appropriate if a longer-term cleanup is anticipated. In longer-term situations where cleanup is required, it may not be productive to engage in protracted up-front discussion of analytical detection limits that are above applicable health-based cleanup levels for certain COCs. Remediating parties typically recognize the need to continue monitoring for such chemicals while deferring further discussion of the detection limit issue until such time as the other COCs that are present (those that can be analytically quantified) are approaching their respective cleanup levels. At that time, the detection limit issue for those problem chemicals with low health- or ecological-based limits would need to be addressed in more detail.

A long-term approach to this issue is to establish an interim target cleanup level corresponding to the site-specific laboratory's method detection limit (assuming that limit is acceptable to the department). This approach would typically be accompanied by a listing or acknowledgement of the lower health-based limit and a contingency that requires remediating parties to change to new, more "sensitive" analytical methods, and therefore updated target levels, if such analytical methods become available during the course of cleanup. Sample language for this approach, as might be included in a work plan, follows:

> The risk-based groundwater cleanup target level for some of the COCs is below the lowest, reasonably achievable method detection limit due to limitations of current analytical technology. The interim groundwater cleanup target level has therefore been set at the method detection limit for those chemicals. A list of the corresponding risk-based concentrations for those chemicals is also provided.
>
> The allowable maximum detection limit for the referenced COCs can never be greater than the interim groundwater cleanup target levels. If the allowable maximum detection limit for specific COCs cannot be achieved due to matrix interferences or other reasonable analytical limitations (appropriate supporting documentation must be provided), the affected sample and associated chemical analyses will be exempted from this requirement. However, such an exemption does not in any way relieve the remediating party from complying with the interim groundwater cleanup target levels.
>
> The department reserves the right to modify the interim groundwater cleanup target levels based on future advances in analytical technology. Any such modifications would be to facilitate comparison of residual concentrations of chemicals in groundwater with then current risk-based groundwater cleanup target levels.

The above approach will most often apply in situations where the remediating party initially chooses to use the DTL or Tier I groundwater concentration as the interim target cleanup level. However, many remediating parties that initially pursue this approach may, after collecting substantial long-term data, choose to pursue a Tier 2 or Tier 3 Risk Assessment to develop, final groundwater cleanup target levels. This may result in the establishment of final cleanup target levels that are above the method detection limits for the problem chemicals, thereby resolving the “detection limit” issue.

If any disparity between target levels and analytical detection limits occurs when determining representative concentrations, see Appendix C.1 for guidance on handling non-detect values.

8.7 STEP 6: IF NECESSARY, CALCULATE CUMULATIVE SITE-WIDE RISK AND COMPARE WITH ACCEPTABLE RISK

For the MRBCA process, the acceptable risk levels are:

Carcinogenic Risk

- The total risk for each chemical, which is the sum of risk for all complete exposure pathways for each chemical, must not exceed 1 x 10^{-5}.
- The cumulative site-wide risk (sum of risk for all chemicals and all complete exposure pathways) must not exceed 1 x 10^{-4}.

Non-carcinogenic Risk

- The hazard index for each chemical, which is the sum of hazard quotients for all complete exposure pathways for each chemical (the total risk), must not exceed 1.0.
- The site-wide hazard index, which is the sum of hazard quotients for all chemicals and all complete exposure pathways, must not exceed 1.0.

If the hazard index exceeds 1.0, a qualified toxicologist may calculate the hazard index corresponding to a specific toxicological end point. In this case, the specific hazard indices for each toxicological end point must be less than unity (1.0).

Step 6 will apply only in cases where the number of COCs and routes of exposure may warrant the calculation of cumulative site-wide risk. In such cases, the project manager should discuss this issue with the remediating party and may request an evaluation to estimate the cumulative site-wide risk. For example, former manufactured gas plants, which often have a multitude of contaminants with high toxicity associated with them, are examples of sites where the cumulative site-wide risk may move the site beyond the acceptable cumulative site-wide IELCR risk level of 1 x 10^{-4} and a Hazard Index of 1. At such a site, the analysis discussed in this step may be required. Other cleanup authorities, such as RCRA and CERCLA, operate under the presumption of equivalence with federal guidance and regulation and may require the consideration of cumulative site-wide risk in all cases.

In the rare instance where Step 6 would be needed, the cumulative site-wide risk is calculated for each receptor using the following two-step process. First, the total risk of each chemical for each complete or potentially complete route of exposure must be calculated.

Second, the total risk for each chemical (sum of risk for all the routes of exposure) and the site-wide risk (sum of risk of all chemicals for all routes) for each receptor must be calculated.

1. Calculate risk for each chemical and each potentially complete exposure pathway:

$$IELCR_{ij} = 1 \times 10^{-5} \times \frac{C_{ij}^{rep}}{C_{ij}^{T1}} \tag{8-1a}$$

$$HQ_{ij} = \frac{C_{ij}^{rep}}{C_{ij}^{T1}} \tag{8-1b}$$

where,

$IELCR_{ij}$	=	Individual excess lifetime cancer risk (IELCR) for chemical *i* and pathway *j*,
HQ_{ij}	=	Hazard quotient (HQ) for chemical *i* and pathway *j*,
C_{ij}^{rep}	=	Representative concentration for chemical *i* and pathway *j*, and
C_{ij}^{T1}	=	Tier 1 target concentration for chemical *i* and pathway *j* from tables in Appendix B.

2. After calculating the risk for each chemical and each route of exposure, calculate the total risk for each chemical and the cumulative site-wide risk:

$$IELCR_{Ci} = \sum_{j=1}^{n} IELCR_{ij} \tag{8-2a}$$

$$HI_{Ci} = \sum_{j=1}^{n} HQ_{ij} \tag{8-2b}$$

$$IELCR_{T} = \sum_{i=1}^{m} IELCR_{Ci} \tag{8-2c}$$

$$HI_{T} = \sum_{i=1}^{m} HI_{Ci} \tag{8-2d}$$

where,

$IELCR_{Ci}$	=	Sum of risk for carcinogenic adverse health effect of all routes of exposure pathway for chemical *i*,
HI_{Ci}	=	Sum of Hazard Index (HI) for non-carcinogenic adverse health effect of all routes of exposure pathway for chemical *i*,
$IELCR_{T}$	=	Cumulative site-wide risk for carcinogenic adverse health effect of all chemicals and all routes of exposure,
HI_{T}	=	Cumulative site-wide Hazard Index for non-carcinogenic adverse health effect of all chemicals and all routes of exposure,
m	=	Total number of chemicals of concern, and
n	=	Total number of complete routes of exposure.

To facilitate the calculation of risk for each chemical and each route of exposure and the cumulative risk, the representative concentrations should be organized as shown in example

Table 8-1(a) and Table 8-1(b) for carcinogenic and non-carcinogenic adverse health effects respectively. A separate table must be developed for each receptor - most commonly residential child, adult, age-adjusted, non-residential worker, and construction worker. Concentration in each cell of Table 8-1(a) is referred to as C_{ij}^{rep}, where *i* refers to any one of the 'm' chemicals of concern, *j* refers to any one of the 'n' pathways, and '*rep*' refers to representative concentration. Tables 8-1(a) and 8-1(b) lists the representative concentrations to be used for the evaluation of human health risk.

To facilitate the calculation of risk in Step 6, target levels from Appendix B can be organized as shown in example Table 8-2(a) and Table 8-2(b) for carcinogenic and non-carcinogenic adverse health effects respectively. As above, a separate table must be developed for each receptor. Each value in Table 8-2(a) is referred to as C_{ij}^{T1}, where *i* refers to any one of the 'm' chemicals of concern, *j* refers to any one of the 'n' pathways, and *T1* refers to the Tier 1 risk-based target level from Appendix B.

To facilitate the above calculations, the risk values may be organized as shown in Table 8-3(a) and Table 8-3(b) for carcinogenic and non-carcinogenic adverse health effects respectively. Tables 8-1 to 8-3 have been developed in a computer spreadsheet, which may be obtained from the department.

Next, the cumulative site-wide risks calculated in this step are compared with acceptable cumulative site-wide risk levels. For carcinogens, cumulative site-wide $IELCR_T$ must be less than 1 x 10^{-4}. Further, if the total $IELCR_{Ci}$ (sum across all pathways) for any one chemical is greater than 1 x 10^{-5}, additional discussions between the remediating party and the department's project manager may be warranted. For non-carcinogenic risk, the site-wide HI_T for all COCs and all complete routes of exposure must be less than 1.0. Further, cumulative HI_{Ci} (over all routes of exposure) for each chemical must be less than 1.0.

8.8 STEP 7: EVALUATE THE NEXT COURSE OF ACTION

Depending on the result of Step 5 and Step 6 (if necessary), one of the following alternatives is possible.

Alternative 1: The remediating party may request that the department issue a letter of completion for the site if:

1. The analysis in Steps 5 or 6 indicates that both the cumulative site-wide risk (all chemicals and all complete pathways, $IELCR_T$ and HI_T) and the risk for each chemical (all pathways, $IELCR_{Ci}$ and HI_{Ci}) for all receptors is acceptable, or
2. The representative concentration for all COCs and all the routes of exposure are below the Tier 1 risk-based target levels.

In each case above, the following four conditions must be met.

Condition 1: The plume, if one exists, is stable or decreasing (refer to Section 6.13.2 for discussion of plume stability). If this condition is not satisfied, the remediating party must continue groundwater monitoring until the plume is demonstrably stable. Actions may be taken to hasten plume stability. This recommendation must include a sampling plan with specifics such as:

- Wells to be sampled,
- Frequency of sampling,
- Laboratory analysis method,
- Method to be used to demonstrate that the plume is stable or shrinking, and
- The format and frequency of reporting requirements.

Condition 2: The maximum concentration of any COC is less than ten times the representative concentration of that COC for any exposure pathway. Note the maximum concentration here refers to the maximum concentration of a chemical in the exposure domain, not the site-wide maximum concentration. This condition can be met if an exceedance can be justified by any of the following and appropriate actions taken:

- The maximum concentration is an outlier,
- The average concentration was inaccurately calculated,
- The site is not adequately characterized,
- A hot spot may not have been adequately characterized, or
- Other explanation satisfactory to the department.

Any exceedance of this condition must be documented and the possible rationale, if any, submitted to the department. The department will determine what actions, if any, will be necessary to address the situation.

Condition 3: Prior to issuance of a letter of completion, adequate assurance is provided that the land use assumptions used in the MRBCA evaluation are not violated for current or future conditions. This condition may require that one or more activity and use limitations (AULs) are placed on the site and plans are in place to maintain long-term stewardship (LTS) for as long as needed to protect human health, public welfare and the environment.

Condition 4: There are no ecological concerns at the site, as determined by the Ecological Risk Assessment, completion of Level 1 Checklists A and/or B, or confirmation that the maximum or representative concentrations are below levels protective of ecological receptors. If this condition is not met, the remediating party must provide recommendations to the department to manage the ecological risk. If the department approves the recommendations, their implementation and effectiveness, then this condition would be met.

Alternative 2: The remediating party must decide either to use the Tier 1 risk-based target levels as the cleanup levels and conduct corrective action to meet these levels or to perform a Tier 2 risk assessment if the analysis finds that:

1. The risk for any chemical (all pathways, $IELCR_{Ci}$ and HI_{Ci}) for any human or ecological receptors exceeds acceptable levels, or
2. The cumulative site-wide risk (all chemicals and all complete pathways, $IELCR_T$ and

HI_T) exceeds acceptable levels, or

3. The representative concentrations in Step 5 exceed the Tier 1 risk-based target levels.

Based on this decision, the remediating party must recommend one of the following:

1. Remediation to Tier 1 risk-based target levels (if the remediating party decides to remediate the site to Tier 1 risk-based target levels, the cleanup levels will be the lower of the concentrations protective of human health, both carcinogenic and non-carcinogenic, and ecological receptors), or
2. Performance of a Tier 2 risk assessment.

The chart below summarizes several combinations of outcomes and necessary actions that can be pursued in lieu of a Tier 2 risk assessment when cumulative site-wide risk is considered.

Action vs. Calculated Risk

Carcinogenic Risk		Non-carcinogenic Risk		Action
Individual	**Cumulative**	**Individual**	**Cumulative**	
NE	NE	NE	NE	No need to calculate any RBTLs.
E	E	E	E	Both carcinogenic and non-carcinogenic RBTLs must be developed
NE	E	NE	E	Both carcinogenic and non-carcinogenic RBTLs must be developed.
E	NE	E	NE	Both carcinogenic and non-carcinogenic RBTLs must be developed.
NE	NE	E	NE	Non-carcinogenic RBTLs must be developed.
NE	NE	NE	E	Non-carcinogenic RBTLs must be developed.
E	NE	NE	NE	Carcinogenic RBTLs must be developed.
NE	E	NE	NE	Carcinogenic RBTLs must be developed.

Notes: E: Exceeds acceptable risk level.
NE: Does not exceed acceptable risk level.
RBTL: Risk-based target level

8.9 STEP 8: DOCUMENT TIER 1 RISK ASSESSMENT AND RECOMMENDATIONS

The Tier 1 risk assessment must be clearly documented, both to facilitate the department's review and to provide information to interested third parties. If a Tier 2 assessment is also conducted, both Tier 1 and Tier 2 assessments may be submitted as one report. At a minimum, the Tier 1 Risk Assessment Report must include the following:

- Site background and chronology of events,
- Data used to perform the evaluation,
- Documentation of the exposure model and its underlying assumptions,
- If cumulative risk calculation is required, the estimated risk for each chemical, each route of exposure, each receptor, each media, and the cumulative site-wide risk for each receptor,
- Recommendations based on the Tier 1 risk assessment (either Tier 2 assessment or preparation of a risk management plan), and
- If a letter of completion is requested, documentation that all four of the conditions in Section 8.7, Alternative 1, have been met.

If any of the representative concentrations at the site are above the Tier 1 risk-based target levels or if the cumulative site-wide risk exceeds acceptable target risk levels, the remediating party may choose to complete a Tier 2 risk assessment in lieu of cleanup to the Tier 1 risk-based target levels. A Tier 2 risk assessment would typically be conducted if the Tier 1 risk is unacceptable and it is not feasible or cost effective to meet Tier 1 risk-based target levels. At sites where a preliminary review of data indicates that the chemicals of concern (COCs) will not meet the Tier 1 levels, a Tier 2 evaluation may be performed directly without performing and submitting a Tier 1 evaluation.

A Tier 2 risk assessment may also be required by the department if the site-specific fate and transport parameters or other site conditions are clearly different from the default assumptions used to develop Tier 1 risk-based target levels. In such cases, a Tier 1 evaluation may not be protective of human health, public welfare and the environment. For example, if the critical route of exposure is indoor inhalation and the volumetric water content in the soil is significantly less than the default value or if the fractional organic carbon content is significantly less than its default value, then Tier 1 risk-based target levels may not be protective of human health, public welfare and the environment.

As noted in Table 2-1, compared to a Tier 1 assessment, a Tier 2 assessment uses site-specific fate and transport parameters or default values if they can be justified.

A Tier 2 risk assessment must include the following steps:

1. Compile site-specific fate and transport parameters,
2. Calculate Tier 2 risk levels,
3. Compare Tier 2 risk levels with acceptable risk,
4. Recommend the next course of action, and
5. Document Tier 2 risk assessment.

Details of each of these steps are presented below.

9.1 STEP 1: COMPILE SITE-SPECIFIC FATE AND TRANSPORT PARAMETERS

A Tier 2 risk assessment allows for the application of site-specific fate and transport parameters. Fate and transport parameters will be considered site-specific if they are:

- Correctly measured on site at the appropriate location using approved methods,
- Literature values that can be justified as being representative of site conditions,
- Default values that can be justified as representative of current conditions at the site or shown to be conservative based on site conditions, or
- Documented values, such as may be obtained from Hazardous Waste Program site files, from a nearby site in a similar hydrogeologic setting.

This section discusses the fate and transport parameters that must be modified, unless the default values are representative of the site and can be justified, for a Tier 2 risk assessment. Refer to Appendix E, Table E-4 for the Tier 1 fate and transport default values. The remediating party must review the site information and select values for each of these parameters and provide justification for the selection of each specific value. For some fate and transport parameters, literature values consistent with the site stratigraphy may be used in lieu of field measurements.

For a variety of reasons (such as soil heterogeneity, climatic changes and measurement uncertainties), fate and transport parameters show considerable variability, hence it is recommended that the remediating party perform sensitivity analysis to understand the impact of the variability on the estimated risk and target levels. In cases that show considerable variability, the department may require such a sensitivity analysis.

9.1.1 Soil Parameters

Dimension of Exposure Domain for Surficial Soil Parallel to Wind (W_a)

This parameter is used to calculate the risk for outdoor inhalation of vapors and particulates from surficial zone. It represents the longest dimension of the exposure domain for direct contact with the surficial soil pathway that is parallel to the wind direction. If wind direction is variable and or unknown at the site, the longest dimension of the exposure domain must be used.

Depth to Subsurface Soil Sources (d_{ts})

This parameter is used to calculate the risk due to indoor inhalation from subsurface soil. Tier 2 requires the use of the actual measured depth of COCs in soil for which risk is calculated. The most conservative value of this parameter would be the shallowest levels at which the COC is detected or an average of the shallowest depths at which the COC was detected from multiple borings within the exposure domain for this pathway. A reasonable value would be a concentration weighted average depth. Either way, the measurements should reflect the distance from the surface to the top of the first zone of impacted soil.

Thickness of Capillary Fringe (h_c)

This parameter is used to calculate the risk due to indoor inhalation from groundwater. The thickness of the capillary fringe must be representative of the site soils/sediments and is primarily dependent on soil grain size. Typically, the thickness of the capillary fringe is based on literature values because direct measurement is impractical. The sum of the thickness of the capillary fringe and the thickness of the vadose zone should equal the depth to groundwater (i.e., $h_c + h_v = L_{gw}$). Note the groundwater vapor emission model assumes that the capillary fringe is uncontaminated. This may not be an accurate assumption as the capillary fringe may be contaminated; hence a conservative estimate as well as a sensitivity analysis for this parameter may be needed.

Thickness of Vadose Zone (h_v)

This parameter is used to calculate the dilution attenuation factor in the vadose zone. At Tier 2, the thickness of the vadose zone is calculated by subtracting the capillary fringe thickness from the depth to groundwater ($L_{gw} – h_c = h_v$).

Vadose Zone Dry Soil Bulk Density (ρ_s)

This parameter is used for the calculation of risk from all indirect routes of exposure that involve equilibrium calculations between various phases. Examples include leaching to groundwater and indoor and outdoor inhalation from soil and groundwater. See Section 6.7.2 for a discussion related to the determination of dry soil bulk density. If multiple measurements from the vadose zone are available or when multiple values are necessary to represent different soil types, use the average value.

Fractional Organic Carbon Content in Vadose Zone (f_{ocv})

This parameter is used for the calculation of risk from all indirect routes of exposure that involve equilibrium calculations between various phases. See Section 6.16 for a discussion of sample collection and laboratory methods. If measurements of fractional organic matter (not the same as fractional organic carbon) are available, the value must be converted to fractional organic carbon as discussed in Section 6.7.5. Where soil lithology is significantly heterogeneous, samples should be collected at each change in lithology and may be composited into one sample for fractional organic carbon content analysis.

If multiple values are available (as is recommended), and if technically appropriate, the average value should be used. For example, assume that soil is impacted between 10 to15 feet below ground surface (bgs) and the water table is at 25 feet bgs. If three soil samples at 5, 12, and 20 feet have been collected for geotechnical parameters, it would not be appropriate to average the values across all three zones. For the evaluation of indoor inhalation from soil, the sample collected at 20 feet is irrelevant because the sample was taken from below the contaminated zone and vapors would move upward; hence, the average of the values from the samples at 5 and 12 feet may be used. Similarly, for soil leaching to the groundwater pathway, the sample collected at 5 feet should not be used because the sample at 5 feet comes from above the contaminated soil and the lecheate would not move upward through this zone. This concept would apply to all the soil geotechnical parameters - fractional organic carbon content, porosity, volumetric water content, and volumetric air content.

If it is not appropriate to use the average value, different values may be used for different routes of exposure.

Porosity in the Vadose Zone (θ_T)

This parameter is used to calculate risk from all indirect routes of exposure that involve equilibrium calculations between various phases. It is also used to calculate the effective diffusion coefficient of the COC in the vadose zone. Both Tier 1 and Tier 2 assessments assume that the porosity of the vadose zone, capillary fringe, and soil that fills the foundation or wall cracks is identical. This assumption is necessary because measuring porosity in the capillary fringe and in foundation and wall cracks is generally not practical. See Section 6.7.3 for a discussion of methods used to estimate porosity. If multiple porosity values are available, an average value should be used. Where total and effective porosity differ or are expected to differ, the effective porosity value must be used.

Volumetric Water Content in Vadose Zone (θ_{ws})

This parameter is used to calculate the risk from all indirect routes of exposure that involve equilibrium calculations between various phases and to calculate the effective diffusion coefficient of COCs in the vadose zone. Volumetric water content is typically measured as discussed in Section 6.7.4 and generally expressed on a weight basis (gravimetric: grams of water/grams of dry soil) and must be converted to a volumetric value (cm^3 of water/cm^3 of soil) as discussed in Section 6.7.4. An average value based on multiple representative samples should be used. Care should be exercised to make sure that water content measurements from the capillary fringe are not assumed to be values representative of the vadose zone. Moisture content values may be obtained from soil samples being analyzed for COCs. (The remediating party must direct their laboratories to report soil COCs concentration on a dry weight basis and the moisture content of each sample).

Volumetric Air Content in Vadose Zone (θ_{as})

This parameter is used for the calculation of risk from all indirect routes of exposure that involve equilibrium calculations between various phases as well as to calculate the effective diffusion coefficient of COCs in the vadose zone. Volumetric air content in the vadose zone is rarely measured but can be calculated as the difference between the total soil porosity and the volumetric water content in the vadose zone (i.e., $\theta_T - \theta_{WS} = \theta_{as}$).

Volumetric Water Content in Capillary Fringe (θ_{wcap})

This parameter is used to estimate the effective diffusion coefficient of COCs in the capillary fringe. Volumetric water content in the capillary fringe is typically estimated as 90 per cent of the total vadose zone soil porosity (i.e., $0.9\theta_T$). Total soil porosity in the capillary fringe is typically assumed to be equal to the total vadose zone porosity.

Volumetric Air Content in Capillary Fringe (θ_{acap})

This parameter is used for the calculation of the effective diffusion coefficient of COCs in the capillary fringe. Volumetric air content in the capillary fringe is rarely measured but can be calculated as the difference between the total soil porosity in the capillary fringe and the volumetric water content in the capillary fringe ($\theta_{Tcap} - \theta_{wcap} = \theta_{acap}$).

Volumetric Water Content in Foundation or Wall Cracks (θ_{wcrack})

This parameter is used to calculate the effective diffusion coefficient of COCs in the foundation or wall cracks. The volumetric water content in soil that fills foundation or wall cracks is assumed to be the same as the volumetric water content of the soil in the vadose zone ($\theta_{wcrack} = \theta_{ws}$).

Volumetric Air Content in Foundation or Wall Cracks (θ_{acrack})

This parameter is used to calculate the effective diffusion coefficient of COCs in the foundation or wall cracks. The volumetric air content in foundation or wall cracks is assumed to be the same as the volumetric air content of the soil in the vadose zone. The latter is determined as described above.

9.1.2 Groundwater Parameters

Depth to Groundwater (L_{gw})

This parameter is used to estimate the risk due to indoor inhalation from groundwater and the dilution attenuation factor in the vadose zone.

Because the depth to groundwater fluctuates due to seasonal variations, the average depth to groundwater should be based on several years of data. Thus, calculating an average depth to groundwater using data collected from several monitoring events over an extended period of time is preferable. If such data are available for multiple wells in an exposure domain, first, the average depth should be calculated for each well. Second, (for modeling purposes) the average of the average depth of all of the wells should be calculated and considered the average depth to groundwater. In areas where there is a systematic long-term water level change, only recent data should be used.

For consistency, static water levels should be used unless justification can be provided for the use of the depth to the "first water encountered while drilling." If data collected over an extended period of time is not available, the site-specific average depth to groundwater should be calculated by determining the depth to groundwater in each well and then averaging the single well water depths. However, where significant differences in static water levels occur across the site, conservatively the shallowest average depth to groundwater should be used (that is, a single well average using data from the well showing the shallowest depth to groundwater).

Width of Groundwater Source Area Perpendicular to Groundwater Flow Direction (Y)

This parameter, as used by Domenico's model, is used to simulate migration in the saturated zone and estimate the saturated zone dilution attenuation factor. This parameter is necessary only in cases where horizontal migration of COCs in the groundwater is quantitatively evaluated. Tier 2 assessment assumes that COCs migrate vertically downward from the area of release to groundwater. By projecting the area of release to the water table, the dimension Y can be estimated. Figure 9-1 shows a schematic of the groundwater source that is considered by Domenico's groundwater model.

Length of Groundwater Source Area Parallel to Groundwater Flow Direction (W_{ga})

This parameter is necessary when the horizontal migration of COCs in groundwater is quantitatively evaluated. As mentioned above, a Tier 2 risk assessment assumes that COCs migrate vertically downward from the area of release to groundwater. Figure 9-1 shows a schematic of the groundwater source that is considered by Domenico's groundwater model. By projecting the area of release to the water table, W_{ga} can be estimated.

Porosity in Saturated Zone (θ_{TS})

Porosity in the saturated zone is necessary only when biodecay is considered in the horizontal migration of COCs. Refer to Section 6.7.3 for methods used to estimate site-specific values of porosity in the saturated zone. If the unsaturated and saturated zone stratigraphies are similar, the saturated zone porosity may be set equal to the vadose zone porosity. If multiple values are available, an average should be used. If the vadose and saturated zone soil stratigraphies are significantly dissimilar, the porosity of the saturated zone must be measured in the field. If a literature value is used, it must be justified based on the site-specific conditions. Where total and effective porosity differ or are expected to differ, the effective porosity value must be used.

Saturated Zone Dry Soil Bulk Density (ρ_{ss})

An accurate estimate of the dry soil bulk density in the saturated zone is essential only when biodecay is considered in the horizontal migration of COCs. Refer to Section 6.7.2 for methods used to estimate site-specific values of saturated zone dry soil bulk density. If the unsaturated and saturated zone stratigraphies are similar, the saturated zone dry soil bulk density may be set equal to the vadose zone dry soil bulk density. If multiple values are available, an average should be used. If the vadose and saturated zone stratigraphies are significantly dissimilar, the dry soil bulk density of the saturated zone must be measured in the field or an appropriate literature value used.

Fractional Organic Carbon Content in Saturated Zone (f_{ocs})

An accurate estimate of the fractional organic carbon content in the saturated zone is essential only when biodecay is considered in the horizontal migration of COCs. Refer to Section 6.7.5 for discussion of this parameter. If a site-specific value for saturated zone fractional organic carbon content is to be used at Tier 2, the value must be determined based on field samples collected below the water table or by choosing a justifiable literature value.

Groundwater Mixing Zone Thickness (δ_{gw})

Mixing zone thickness is used by Summers and Domenico's model to estimate the dilution attenuation factors in the saturated zone. The groundwater mixing zone thickness is a measure of the thickness over which COCs mix within the saturated zone, primarily due to water table fluctuations. While difficult to estimate accurately, the mixing zone thickness may be approximated based either on photoionization detector (PID) readings, soil concentrations measured in borings extending below the water table or by measuring groundwater concentrations at various depths. The 200 cm Tier 1 default value should be considered a minimum. The USEPA's Soil Screening Guidance (1996, page 45, equation 45) contains an equation to calculate the groundwater mixing zone thickness that may be used at Tier 2. Other procedures for determining the mixing zone thickness may be used with the prior approval of the department. The mixing zone thickness should not exceed the thickness of the aquifer.

Groundwater Darcy Velocity (U_{gw})

This parameter may be used by models that calculate soil and groundwater target concentrations protective of the domestic use of water, such as the Summers and Domenico's model to estimate the dilution attenuation factors in the saturated zone. At Tier 2, the groundwater Darcy velocity must be a site-specific value. The value is the product of the saturated zone hydraulic conductivity and the hydraulic gradient.

Site-specific hydraulic conductivity can be estimated based on the results of site-specific pump tests, if available, or using literature values based on site-specific lithology. The hydraulic gradient should be estimated (as the average gradient) using groundwater elevation data not more than two years old. At sites where the groundwater flow direction shows marked variations, the hydraulic gradient and, hence, the Darcy velocity may need to be estimated for more than one direction and/or a range of velocities presented.

Infiltration Rate (I)

This parameter is used by Summers model to estimate the dilution attenuation factor in the groundwater mixing zone. Unless site-specific information is available, the infiltration rate may be estimated as 10 per cent of the average annual rainfall at the site. Average annual rainfall values are based on a 30-year average and may be obtained from literature.

9.2 STEP 2: CALCULATE TIER 2 RISK

Step 2 estimates the carcinogenic and non-carcinogenic risk for all COCs, receptors and routes of exposure. At Tier 2, risk values must be individually calculated for each COC and each complete route of exposure as per the exposure model. Then, the total risk for each COC and the cumulative site-wide risk must be calculated.

In calculating the Tier 2 risk, the models, physical-chemical properties, toxicological properties, and exposure factors will be the same as used in the Tier 1 risk calculations and are presented in Appendix E.

As discussed in Section 6, Ecological Risk Assessment, the remediating party must also identify appropriate levels protective of ecological receptors if needed.

9.3 STEP 3: COMPARE TIER 2 RISK WITH ACCEPTABLE RISK LEVELS

In Step 3, Tier 2 risks for each COC as well as the total site-wide risk will be compared with their respective acceptable risk level. The total acceptable individual excess lifetime cancer risk (IECLR) for each COC is 1 x 10^{-5}. The acceptable risk level for the site-wide cumulative IECLR is 1 x 10^{-4}. The acceptable hazard quotient (HQ) for each COC and each route of exposure as well as the hazard index (HI: sum of HQ) is 1. The comparison will result in the following possibilities:

- The calculated IELCR for each COC and the cumulative site-wide IELCR are below the acceptable risk levels. In this case, it will not be necessary to develop Tier 2 site-specific target levels for carcinogenic effects.

- Either the individual COC or the cumulative site-wide IELCR exceeds the acceptable risk level. In this case, Tier 2 site-specific target levels must be developed. As explained in Appendix I, considerable flexibility is allowed in the calculation of site-specific target levels. Therefore, the remediating party must carefully explain the method and the assumptions used to calculate the target levels.

- The calculated cumulative site-wide hazard index (sum of the hazard quotients for all chemicals for all routes of exposure) is acceptable (less than 1.0). In this case, the non-carcinogenic risk is deemed acceptable and it will not be necessary to develop Tier 2 site-specific target levels for non-carcinogenic adverse health effects.

- The hazard quotient for each COC is acceptable (less than unity), but the site-wide hazard index is unacceptable (greater than unity). In this case, it may be appropriate to segregate the COCs by target organ, system or mode of action and derive hazard indices for each. As an example, if there are 10 COCs at a site, four of which affect the kidney only, three affect the central nervous system only, and three affect the liver only. In this case, the COCs may be grouped into three categories, those that affect the (1) kidney, (2) central nervous system, and (3) liver. A cumulative hazard index for each of these organs must be developed. In this example, the remediating party would develop three cumulative hazard indices: one each for the kidney, central nervous system and the liver. If each of these cumulative hazard indices is acceptable (less than one), it will not be necessary to develop Tier 2 site-specific target levels for these COCs for non-carcinogenic health effects. If not acceptable, it will be necessary to develop the target levels for the COCs in the group that exceed the hazard index of unity.

  A toxicologist must perform the analysis that is conceptually described above. Note that COCs may affect multiple organs and have multiple adverse health effects. In calculating the Hazard Index, COCs with multiple effects must be included in each category of organ that the COC affects.

In addition to the above human health risk evaluation, the representative concentrations must also be compared with the ecological screening levels if needed and identified in Step 2.

9.4 ANALYTICAL DETECTION LIMITS

During the course of demonstrating that target concentrations have been achieved, the analytical detection limit for certain COCs in environmental media may be higher (sometimes by orders of magnitude) than the corresponding Tier 2 target cleanup level for that chemical. This happens because the concentrations of chemicals that can be positively detected are limited by the capabilities of the analytical method used.

For information purposes, the following have been identified in Appendix B:

- COCs with DTLs or Tier 1 RBTLs lower than the detection limit or Practical Quantitation Limit (PQL) of current analytical methods, and
- COCs that do not have a standard method listed in SW-846.

This discussion identifies the approaches that may be used in instances where the target cleanup level for a particular COC(s) cannot be achieved using standard analytical methods. In such circumstances, approaches that may be useful include:

1. Check the data to confirm that the standard detection limits are indeed higher than the Tier 2 target cleanup levels and that no errors were committed (for example, transposing numbers, unit conversion, or misplacing a decimal point),
2. With department approval, use alternative analytical methods that achieve lower detection limits than the Tier 2 target levels.
3. Perform a more focused risk assessment to determine if the levels that can be analytically quantified are protective of human health and the environment given the complete and/or potentially complete exposure pathways. This approach could involve the use of a detection-based scenario (i.e., using the maximum detection limit of the COCs) in conjunction with alternate site-specific exposure factors to calculate if the risk is acceptable.
4. Develop areal contaminant trends that can then be used to extrapolate contaminant extent to the target level(s) followed by calculation of average concentrations based on those extrapolations. Fate and transport models used in conjunction with "above analytical detection limit results" for certain problematic chemicals could also be used to extrapolate contaminant extent, thereby facilitating calculation of average concentrations for comparison to target cleanup levels.

These approaches may be most useful where short-term decisions regarding the completion of cleanup are desired. Other approaches may be appropriate if a longer-term cleanup is anticipated. In longer-term situations where cleanup is required, it may not be productive to engage in protracted up-front discussion of analytical detection limits that are above applicable health-based cleanup levels for certain COCs. Remediating parties typically recognize the need to continue monitoring for such chemicals while deferring further discussion of the detection limit issue until such time as the other COCs that are present (those that can be analytically quantified) are approaching their respective cleanup levels. At that time, the detection limit issue for the problem chemicals with low health- or ecological-based limits would need to be addressed in more detail.

A long-term approach to this issue is to establish an interim target cleanup level corresponding to the site-specific laboratory's method detection limit (assuming that limit is acceptable to the department). This approach would typically be accompanied by a listing or acknowledgement of the lower health-based limit and a contingency that requires remediating parties to change to new, more "sensitive" analytical methods, and therefore updated target levels, if such analytical methods become available during the course of cleanup. Sample language for this approach, as might be included in a work plan, follows:

> The risk-based groundwater cleanup target level for some of the COCs is below the lowest, reasonably achievable method detection limit due to limitations of current analytical technology. The interim groundwater cleanup target level has therefore been set at the method detection limit for those chemicals. A list of the corresponding risk-based concentrations for those chemicals is also provided.
>
> The allowable maximum detection limit for the referenced COCs can never be greater than the interim groundwater cleanup target levels. If the allowable maximum detection limit for specific COCs cannot be achieved due to matrix interferences or other reasonable analytical limitations (appropriate supporting documentation must be provided), the affected sample and associated chemical analyses will be exempted from this requirement. However, such an exemption does not in any way relieve the remediating party from complying with the interim groundwater cleanup target levels.
>
> The department reserves the right to modify the interim groundwater cleanup target levels based on future advances in analytical technology. Any such modifications would be to facilitate comparison of residual concentrations of chemicals in groundwater with then current risk-based groundwater cleanup target levels.

The above approach will most often apply in situations where the remediating party initially chooses to use the DTL or Tier I risk based target level as the interim target cleanup level. However, many remediating parties that initially pursue this approach may, after collecting substantial long-term data, choose to pursue a Tier 3 Risk Assessment to develop final cleanup target levels. This may result in the establishment of final cleanup target levels that are above the method detection limits for those chemicals, thereby resolving the "detection limit" issue.

If any disparity between target levels and analytical detection limits occurs when determining representative concentrations, see Appendix C.1 for guidance on handling non-detect values.

9.5 STEP 4: RECOMMEND THE NEXT COURSE OF ACTION

Depending on the results of the comparison, one of the following alternatives is available:

Alternative 1: The remediating party may request that the department issue a letter of completion for the site if:

1. The analysis in Steps 5 or 6 indicates that both the cumulative site-wide risk (all chemicals and all complete pathways, $IELCR_T$ and HI_T) and the risk for each chemical (all pathways, $IELCR_{Ci}$ and HI_{Ci}) for all receptors is acceptable or
2. The representative concentration for all COCs and all the routes of exposure are below the Tier 2 site-specific target levels.

In each case above, the following four conditions must be met.

Condition 1: The plume, if one exists, is stable or decreasing (refer to Section 6.13.2 for discussion of plume stability). If this condition is not satisfied, the remediating party must continue groundwater monitoring until the plume is demonstrably stable. Actions may be taken to hasten plume stability. This recommendation must include a sampling plan with specifics such as:

- Wells to be sampled,
- Frequency of sampling,
- Laboratory analysis method,
- Method to be used to demonstrate that the plume is stable or shrinking, and
- The format and frequency of reporting requirements.

Condition 2: The maximum concentration of any COC is less than ten times the representative concentration of that COC for any exposure pathway. Note the maximum concentration here refers to the maximum concentration of a chemical in the exposure domain, not the site-wide maximum concentration. This condition can be met if an exceedance can be justified by any of the following and/or appropriate actions taken:

- The maximum concentration is an outlier,
- The average concentration was inaccurately calculated,
- The site is not adequately characterized,
- A hot spot may not have been adequately characterized, or
- Other explanation satisfactory to the department.

Any exceedance of this condition must be documented and the possible rationale, if any, submitted to the department. The department will determine what actions, if any, will be necessary to address the situation.

Condition 3: Prior to issuance of a Letter of Completion, adequate assurance is provided that the land use assumptions used in the MRBCA evaluation are not violated for current or future conditions. This condition may require that one or more activity and use limitations (AULs) are placed on the site and plans are in place to maintain long-term stewardship (LTS) for as long as needed to protect human health, public welfare and the environment.

Condition 4: There are no ecological concerns at the site, as determined by the Ecological Risk Assessment, completion of Checklists A and/or B, or confirmation that the maximum or representative concentrations are below levels protective of ecological receptors. If this condition is not met, the remediating party must provide recommendations to the department to manage the ecological risk. If the department approves the recommendations, their implementation and effectiveness, then this condition would be met.

Alternative 2: The remediating party must decide either to use the calculated Tier 2 site specific target levels as the cleanup levels and conduct corrective action to meet these levels or to perform a Tier 3 risk assessment if the analysis finds that:

1. The risk for any chemical (all pathways, $IELCR_{Ci}$ and HI_{Ci}) for any human or ecological receptors exceeds acceptable levels, or
2. The cumulative site-wide risk (all chemicals and all complete pathways, $IELCR_T$ and HI_T) exceeds acceptable levels, or
3. The representative concentrations exceed the calculated Tier 2 site specific target levels.

Based on this decision, the remediating party must recommend one of the following:

1. Remediation to Tier 2 site-specific target levels (if the remediating party decides to remediate the site to Tier 2 site-specific target levels, the cleanup levels will be the lower of concentrations protective of human health, both carcinogenic and non-carcinogenic, and ecological receptors), or
2. Performance of a Tier 3 risk assessment.

The chart below summarizes several combinations of outcomes and necessary actions that can be pursued in lieu of a Tier 3 risk assessment when cumulative site-wide risk is considered.

Action vs. Calculated Risk

Carcinogenic Risk		Non-carcinogenic Risk		Action
Individual	Cumulative	Individual	Cumulative	

NE	NE	NE	NE	No need to calculate any SSTLs.
E	E	E	E	Both carcinogenic and non-carcinogenic SSTLs must be developed.
NE	E	NE	E	Both carcinogenic and non-carcinogenic SSTLs must be developed.
E	NE	E	NE	Both carcinogenic and non-carcinogenic SSTLs must be developed.
NE	NE	E	NE	Non-carcinogenic SSTLs must be developed.
NE	NE	NE	E	Non-carcinogenic SSTLs must be developed.
E	NE	NE	NE	Carcinogenic SSTLs must be developed.
NE	E	NE	NE	Carcinogenic SSTLs must be developed.

Notes:
E: Exceeds acceptable risk level (refer to Appendix B)
NE: Does not exceed acceptable risk level
SSTL: Site-specific target level

9.6 STEP 5: DOCUMENT TIER 2 RISK ASSESSMENT AND RECOMMENDATIONS

To facilitate the review of the Tier 2 risk assessment by the department and other interested parties, the risk assessment must be clearly documented. If a Tier 1 risk assessment is also conducted, both Tier 1 and Tier 2 risk assessments may be submitted as one report. At a minimum, the Tier 2 risk assessment report must include the following:

- Site background and chronology of events,
- Data used to perform the evaluation,
- Documentation of the exposure model and its assumptions,
- Documentation and justification of all fate and transport parameters,
- Estimated risk for each COC, each route of exposure, each receptor, and the cumulative site-wide risk for each receptor and media,
- Recommendations based on the Tier 2 risk assessment, and
- If a Letter of Completion is requested, documentation that all four of the conditions in Section 9.4, Alternative 1, have been met.

A Tier 3 risk assessment is a detailed, site-specific evaluation that the remediating party may choose to conduct when Tier 2 risks exceed acceptable levels and it is not cost-effective or feasible to remediate the site to Tier 2 site-specific target levels.

As shown in Table 2-1, compared to a Tier 2 assessment, a Tier 3 assessment may use the most recent toxicity factors, physical and chemical properties, site-specific exposure factors, and alternative models. A Tier 3 risk assessment may include a Level 1, Level 2, or Level 3 ecological risk assessment as described in Section 6.11.

The Tier 3 risk assessment requires the following steps:

1. Develop a Tier 3 work plan,
2. Collect additional data, if necessary,
3. Calculate Tier 3 risk,
4. Compare Tier 3 risk with acceptable risk levels and if necessary, develop clean-up levels,
5. Recommend the next course of action, and
6. Complete a Tier 3 Risk Assessment Report.

10.1 STEP 1: DEVELOP A TIER 3 WORK PLAN

Tier 3 risk assessment provides considerable flexibility to the remediating party. Examples are:

- Evaluation of additional site-specific receptors (other than residential and non-residential considered in Tier 1 and Tier 2) such as recreational users or trespassers,
- Use of site-specific exposure factors,
- Use of toxicity values different than the values listed in Appendix E, Table E-1, and may include the use of subchronic toxicity values for non-carcinogenic effects when the exposure duration is less than seven years,
- Use of alternative fate and transport models, and
- Alternative definition of surface soils based on site-specific considerations.

In each case, the specific choice must be technically justified. Because of this flexibility and the very site-specific nature of the Tier 3 evaluations, the department must approve a Tier 3 work plan.

In Tier 3, the only receptors that need to be considered are those for which the risk in Tier 2 exceeds acceptable levels and any additional receptors that are identified in Tier 3. Receptors for whom the Tier 2 risk is not exceeded need not be evaluated. However, none of the chemicals of concern (COCs) considered in the Tier 2 risk assessment can be eliminated at Tier 3. Thus the COCs considered in Tier 2 and Tier 3 assessments would be identical, unless new data collected subsequent to the Tier 2 assessment indicates otherwise. Typically a Tier 3 assessment follows a Tier 2 assessment. However, in a few cases it may be appropriate to proceed directly to a Tier 3 assessment after a DTL or Tier 1 assessment or after a site characterization.

The technical portion of the work plan must, at a minimum, include the following:

- Identification of the receptors that will be evaluated in Tier 2.

- Identification of the COCs and the complete and potentially complete routes of exposure for which Tier 3 risk will be calculated. Typically, these would be the same as for a Tier 2 evaluation.

- An explanation of the fate and transport models to be used for the calculation of risk for the complete and potentially complete routes of exposure. The remediating party may propose the use of a model(s) different than that used in Tier 1 or Tier 2 assessment. At a minimum, the proposed model must:
  (i) Be peer reviewed,
  (ii) Be publicly available or a copy provided to the department at no cost to the department,
  (iii) Have a history of use on similar projects, and
  (iv) Be technically defensible.

- A tabulation of the input parameters required to compute the Tier 3 risk. For each of these parameters, the remediating party must justify the use of the selected value. Examples of input parameters that may be specific to Tier 3 are:
  (i) Chemical-specific physical properties,
  (ii) Chemical-specific toxicological properties,
  (iii) Site-specific or other alternate exposure factors, and
  (iv) Media and site-specific parameters required by the selected fate and transport models.

  In (iii), if alternative exposure factors are used for the inhalation pathway, the remediating party must review and adjust as appropriate both the inhalation exposure time (hours/day) and inhalation rate (m^3/hour).

- A discussion of the data and the methodology that will be used to calculate the representative concentrations.

- An explanation of data gaps, if any, that require additional fieldwork. A scope of work for the collection of this data must be included in the Tier 3 risk assessment work plan.

- A discussion of the variability and uncertainty in the input parameters and the manner in which the impact of this variability on the final risk will be evaluated. Uncertainty analysis techniques range from sensitivity analysis to detailed Monte Carlo simulations.

- An evaluation of ecological risk. Ecological Risk Assessments previously completed at any tier are also acceptable in Tier 3 and do not need to be re-done.

After receiving approval of the Tier 3 work plan, the remediating party can perform a Tier 3 risk assessment. Any changes to the methodology or input parameters made subsequent to the department's approval must also be approved by the department and documented by the remediating party.

10.2 STEP 2: COLLECT ADDITIONAL DATA, IF NECESSARY

Upon approval of the work plan, the remediating party must perform the necessary fieldwork to collect the data. Any changes in the data collection due to field conditions or logistics of fieldwork must be discussed with the department prior to completion of the field effort. Depending on the nature and type of field work and data gaps, it may not be necessary to submit a separate report to the department describing the data collection activities. Documentation of the data collection efforts may be included as an appendix to the Tier 3 report.

10.3 STEP 3: CALCULATE TIER 3 RISK

Step 3 estimates the carcinogenic and non-carcinogenic risk for all COCs, receptors and routes of exposure, using the models and data in accordance with the approved work plan. At Tier 3, the risk values must be calculated for each COC and each route of exposure. Then, the total risk for each COC (sum of risk for all the complete routes of exposure for a chemical) and the cumulative site-wide risk (sum of risk for all COCs and all complete routes of exposure) must be calculated. If needed, ecological risk should also be considered as per the work plan.

10.4 STEP 4: COMPARE TIER 3 RISKS WITH ACCEPTABLE RISK LEVELS AND IF NECESSARY, DEVELOP CLEAN-UP LEVELS

In Step 4, total risks for each COC as well as cumulative site-wide risk for each receptor are compared with their respective acceptable risk levels. The total acceptable individual excess lifetime cancer risk (IECLR) for each COC is 1×10^{-5}. The acceptable risk level for the site-wide cumulative IECLR is 1×10^{-4}. The total acceptable Hazard Index (HI) for each COC and all routes of exposure as well as the cumulative site-wide Hazard Index is 1. The comparison will result in the following possibilities:

- The calculated total IECLR for each COC and the site-wide cumulative IECLR are below the acceptable risk levels. In this case, it will not be necessary to develop Tier 3 site-specific target levels for carcinogenic COCs.

- Either the individual chemical or the cumulative site-wide IECLR exceeds the acceptable risk level. In this case, Tier 3 site-specific target levels must be developed. As explained in Appendix I, considerable flexibility is allowed in the calculation of the site-specific target levels. Therefore, the remediating party must carefully explain the method and the assumptions used to calculate the target levels.

- The calculated cumulative site-wide hazard index (sum of the hazard quotients for all chemicals for all routes of exposure) is acceptable (less than 1.0). In this case, the non-carcinogenic risk is deemed acceptable and it will not be necessary to develop Tier 3 site-specific target levels for non-carcinogenic health effects.

- The hazard quotient for each COC is acceptable (less than unity), but the site-wide hazard index is unacceptable (greater than unity). In this case, it may be appropriate to segregate the COCs by target organ, system or mode of action and derive hazard indices for each. As an example, if there are 10 COCs at a site, four of which affect the kidney only, three affect the central nervous system only, and three affect the liver only. In this case, the COCs may be grouped into three categories, those that affect the (1) kidney, (2) central nervous system, and (3) liver. A cumulative hazard index for each of these organs must be developed. In this example, the remediating party would develop three cumulative hazard indices: one each for the kidney, central nervous system and the liver. If each of these cumulative hazard indices is acceptable (less than one), it will not be necessary to develop Tier 3 site-specific target levels for these COCs for non-carcinogenic health effects. If not acceptable, it will be necessary to develop the target levels for the COCs in the group that exceed the hazard index of unity.

  A toxicologist must perform the analysis that is conceptually described above. Note that COCs may affect multiple organs and have multiple adverse health effects. In calculating the Hazard Index, COCs with multiple effects must be included in each category of organ that the COC affects.

In addition to the human health risk assessment, ecological risks or levels protective of ecological receptors must be considered.

10.5 ANALYTICAL DETECTION LIMITS

During the course of demonstrating that target concentrations have been achieved, the analytical detection limit for certain COCs in environmental media may be higher (sometimes by orders of magnitude) than the corresponding Tier 3 target cleanup level for that chemical. This happens because the concentrations of chemicals that can be positively detected are limited by the capabilities of the analytical method used.

For information purposes, the following have been identified in Appendix B:
- COCs with DTLs or Tier 1 RBTLs lower than the detection limit or Practical Quantitation Limit (PQL) of current analytical methods and
- COCs that do not have a standard method listed in SW-846.

This discussion identifies the approaches that may be used in instances where the target cleanup level for a particular COC(s) cannot be achieved using standard analytical methods. In such circumstances, the following approaches may be useful:

1. Check the data to confirm that the standard detection limits are indeed higher than the Tier 3 target cleanup levels and that no errors were committed (for example, transposing numbers, misplacing a decimal point, or unit conversion),
2. With department approval, use alternative analytical methods that achieve detection limits lower than the Tier 3 target levels.
3. Perform a more focused risk assessment to determine if the levels that can be analytically quantified for the problem chemical are protective of human health and the environment given the complete and/or potentially complete exposure pathways. This approach could involve the use of a detection-based scenario (i.e., using the maximum detection limit of the problem COCs) in conjunction with alternate site-specific exposure factors to calculate if the risk is acceptable.
4. Develop areal contaminant trends that can then be used to extrapolate contaminant extent to the target level(s) followed by calculation of average concentrations based on those extrapolations. Fate and transport models used in conjunction with “above analytical detection limit results” for certain problematic chemicals could also be used to extrapolate contaminant extent, thereby facilitating calculation of average concentrations for comparison to target cleanup levels.

These approaches may be most useful where short-term decisions regarding the completion of cleanup are desired. Other approaches may be appropriate if a longer-term cleanup is anticipated. In longer-term situations where cleanup is required, it may not be productive to engage in protracted up-front discussion of analytical detection limits above applicable health-based cleanup levels for certain COCs. Remediating parties typically recognize the need to continue monitoring for such chemicals while deferring further discussion of the detection limit issue until such time as the other COCs that are present (those that can be analytically quantified) are approaching their respective cleanup levels. At that time, the detection limit issue for the problem chemicals with low health- or ecological-based limits would need to be addressed in more detail.

A long-term approach to this issue is to establish an interim target cleanup level corresponding to the site-specific laboratory's method detection limit (assuming that limit is acceptable to the department). This approach would typically be accompanied by a listing or acknowledgement of the lower health-based limit and a contingency that requires remediating parties to change to new, more “sensitive” analytical methods, and therefore updated target levels, if such analytical methods become available during the course of cleanup. Sample language for this approach, as might be included in a work plan, follows:

> The risk-based groundwater cleanup target level for some of the COCs is below the lowest, reasonably achievable method detection limit due to limitations of current analytical technology. The interim groundwater cleanup target level has therefore been set at the method detection limit for those chemicals. A list of the corresponding risk-based concentrations for those chemicals is also provided.
>
> The allowable maximum detection limit for the referenced COCs can never be greater than the interim groundwater cleanup target levels. If the allowable maximum detection limit for specific COCs cannot be achieved due to matrix interferences or other reasonable analytical limitations (appropriate supporting

documentation must be provided), the affected sample and associated chemical analyses will be exempted from this requirement. However, such an exemption does not in any way relieve the remediating party from complying with the interim groundwater cleanup target levels.

The department reserves the right to modify the interim groundwater cleanup target levels based on future advances in analytical technology. Any such modifications would be to facilitate comparison of residual concentrations of chemicals in groundwater with then current risk-based groundwater cleanup target levels.

The above approach will most often apply in situations where the remediating party initially chooses to use the DTL or Tier I risk based target levels as the interim target cleanup level. The Tier 3 analysis may resolve this issue as more site-specific target cleanup levels are developed, in that it will result in the establishment of final cleanup target levels that are above the method detection limits.

If any disparity between target levels and analytical detection limits occurs when determining representative concentrations, see Appendix C.1 for guidance on handling non-detect values.

10.6 STEP 5: DETERMINE THE NEXT COURSE OF ACTION

After completion of the Tier 3 risk assessment, one of the following two alternatives is available:

Alternative 1: The remediating party may request a Letter of Completion from the department if the calculated risks for each COC and the cumulative site-wide risk do not exceed the target risk levels and the following four conditions are met.

Condition 1: The plume, if one exists, is stable or decreasing (refer to Section 6.13.2 for discussion of plume stability). If this condition is not satisfied, the remediating party must continue groundwater monitoring until the plume is demonstrably stable. Actions may be taken to hasten plume stability. This recommendation must include a sampling plan with specifics such as:

- Wells to be sampled,
- Frequency of sampling,
- Laboratory analysis method,
- Method to be used to demonstrate that the plume is stable or shrinking, and
- The format and frequency of reporting requirements.

Condition 2: The maximum concentration of any COC is less than ten times the representative concentration of that COC for any exposure pathway. Note the maximum concentration here refers to the maximum concentration of a chemical in the exposure domain, not the site-wide maximum concentration. This condition can be met if an exceedance can be justified by any of the following and/or appropriate actions taken:

- The maximum concentration is an outlier,
- The average concentration was inaccurately calculated,
- The site is not adequately characterized,
- A hot spot may not have been adequately characterized, or
- Other explanation satisfactory to the department.

Any exceedance of this condition must be documented and the possible rationale, if any, submitted to the department. The department will determine what actions, if any, will be necessary to address the situation.

Condition 3: Prior to issuance of a letter of completion, adequate assurance is provided that the land use assumptions used in the MRBCA evaluation are not violated for current or future conditions. This condition may require that one or more activity and use limitations (AULs) are placed on the site and plans are in place to maintain long-term stewardship (LTS) for as long as needed to protect human health, public welfare and the environment.

Condition 4: There are no ecological concerns at the site, as determined by the Ecological Risk Assessment, completion of Checklists A and/or B, or confirmation that the maximum or representative concentrations are below levels protective of ecological receptors. If this condition is not met, the remediating party must provide recommendations to the department to manage the ecological risk. If the department approves the recommendations, their implementation and effectiveness, then this condition would be met.

Alternative 2: The remediating party must develop site-specific target levels and propose remedial actions to achieve these levels if the analysis finds that either:

1. The total risk for each COC (all pathways, $IELCR_{Ci}$ and HI_{Ci}) is unacceptable for any of the human or ecological receptors, or
2. The cumulative site-wide risk (all COCs and all complete pathways, $IELCR_T$ and HI_T) is unacceptable for any of the human or ecological receptors.

The site-specific target levels and the methodologies used to achieve these levels must be included in the Risk Management Plan.

The chart below summarizes several combinations of outcomes and necessary actions when cumulative site-wide risk is considered.

Action vs. Calculated Risk

Carcinogenic Risk		Non-carcinogenic Risk		Action
Individual	Cumulative	Individual	Cumulative	
NE	NE	NE	NE	No need to calculate any SSTLs.
E	E	E	E	Both carcinogenic and non-carcinogenic SSTLs must be developed.
NE	E	NE	E	Both carcinogenic and non-carcinogenic SSTLs must be developed.
E	NE	E	NE	Both carcinogenic and non-carcinogenic SSTLs must be developed.
NE	NE	E	NE	Non-carcinogenic SSTLs must be developed.
NE	NE	NE	E	Non-carcinogenic SSTLs must be developed.
E	NE	NE	NE	Carcinogenic SSTLs must be developed.
NE	E	NE	NE	Carcinogenic SSTLs must be developed.

Notes:
E: Exceeds acceptable risk level (refer to Appendix B)
NE: Does not exceed acceptable risk level
SSTL: Site-specific target level

10.7 STEP 6: DOCUMENT TIER 3 RISK ASSESSMENT AND RECOMMENDATIONS

Because a Tier 3 risk assessment is very site-specific, the remediating party must submit a report that clearly describes the data used, methodology and key assumptions, results, and recommendations regarding the path forward. Any deviation from the approved scope of work, the rationale for the deviation, and the date when the deviation was approved by the department must be clearly documented in the report. At a minimum the report must include:

- Site background and chronology of events,
- Data used to perform the evaluation,
- Documentation of the exposure model and its assumptions,
- Documentation and justification of all input parameters used,
- Estimated risk for each COC, each route of exposure, each receptor, and the site-wide

risk for each receptor and media,

- Recommendations based on the Tier 3 risk assessment, and
- If a Letter of Completion is requested, documentation that all the conditions in Section 10.5, Alternative 1, have been met.

The effort required to prepare the final report can be significantly reduced by preparing a detailed work plan up front.

11.0
LONG-TERM STEWARDSHIP FOR RISK-BASED CORRECTIVE ACTION SITES

11.1 BACKGROUND

The purpose of Long-Term Stewardship (LTS) is to insure the productive and safe reuse of properties where residual contamination will remain in place. The success of Missouri risk-based corrective action (MRBCA) depends on effective LTS. It is difficult to overstate the importance of controlling future land use and site activities in relation to the success of risk-based corrective action. Virtually every aspect of this guidance – determining exposure pathways, applicable cleanup standards, risk management plans – depends on expectations for future land use and site activities. Institutional controls and engineering controls, where used, are a component of the cleanup decisions under MRBCA, and they must be effective for the program to be successful.

Various terms have been used to refer to land use controls, including "institutional controls (ICs), activity and use limitations (AULs), and long-term stewardship (LTS). Risk-based remedies often rely on these tools to ensure that people do not disturb residual contamination, engineering control measures or otherwise violate the assumptions used in developing site specific Risk Management Plans. This guidance uses the term "Activity and Use Limitations" because it was used throughout the Risk-Based Remediation Rule Workgroup process and is familiar to the participants in the guidance development process (see Appendix L for definitions). In performing risk-based corrective action, preventing unacceptable exposures or releases of hazardous substances may be achieved by removing the contamination entirely, or by managing exposure pathways from contamination to a "receptor" (such as a person or the natural environment). AULs clearly play a vital role in risk-based corrective action by facilitating cost-effective solutions to environmental problems and thereby supporting timely redevelopment of sites. AULs are a key element in ensuring redevelopment and reuse of formerly contaminated properties.

This section provides guidance for establishing the necessary AULs to provide sustainable protection for risk-based remedies. This guidance provides the minimum level of AULs necessary. Specific authorities (such as RCRA and CERCLA) may provide for controls that exceed these requirements. Any specific controls that are required by the authority supervising a cleanup must be met.

Missouri does not have a uniform method of establishing AULs at particular sites for specific purposes. This guidance fills that void, to the extent necessary for MRBCA, with procedures for environmental covenants and local ordinances. MRBCA decisions are presently occurring on a continuing basis so that the process promotes redevelopment and takes advantage of the work that has been done. The elements of these procedures may vary somewhat from site to site and the lack of complete uniformity may continue to pose challenges for the real estate and redevelopment sectors. Toward a standard solution, the Uniform Environmental Covenants Act (UECA) could be adopted in Missouri. This proposal would add uniformity, transparency and consistency in MRBCA cleanups where contamination remains on site (National Conference of Commissioners on Uniform State Laws, 2003). The parties involved can be comfortable with risk-based decisions that are tailored to specific uses of properties that do not require complete cleanup of contamination if, and only if, proposed Risk Management Plans ensure that knowledge of residual contamination is and remains readily available and easily accessible. Any future UECA system would be expected to contain provisions to track and provide information regarding the presence of residual contamination as long as such contamination may pose a potential threat to human health or the environment. This guidance would be revised if the UECA becomes state law.

Most analysis written on the subject of AULs recommends redundant controls rather than minimal controls because of the high level of uncertainty in the long-term effectiveness of AULs (Pendergrass, 2000; NAS, 2000; Probst and McGovern, 1998). Earlier guidance for cleanup at underground storage tank sites (Missouri Department of Natural Resources, February 2004) required only minimal controls largely because environmental releases at underground storage tank sites are generally limited in size and scope, and because the guidance emphasized contaminant removal at these sites. The department later determined that AULs could differ between sites with residual contamination that resulted from cleanup of petroleum releases versus other sites with technically similar contamination (such as benzene, xylene, toluene, and ethylbenzene (James Werner letter to Diane Miller and Ron Leone, January 23, 2003).

The safe reuse of contaminated properties has become an increasingly important goal at national, state and local levels. Providing opportunities for local communities and other interested parties to reuse these properties can help to revitalize local economies and surrounding communities. This guidance provides the minimum controls needed to accomplish LTS under MRBCA. Specific authorities (such as RCRA and CERCLA) may provide for controls that exceed these requirements. Any specific controls that are required by the authority governing a particular cleanup must be met. AULs apply whenever contaminants of concern exceed unrestricted use levels.

The department will approve a Risk Management Plan where the proposed controls and limitations are consistent with this guidance and any other controls or limitations that are required by the specific legal authority governing the cleanup.

11.2 LONG-TERM STEWARDSHIP PRINCIPLES

The following principles offer a broad approach and direction for LTS functions and activities in risk-based corrective action. LTS is the system of activities required to protect human health and the environmental from hazards remaining after cleanup is complete.

1. <u>Protectiveness</u>. Stewardship tools must ensure ongoing protection of human health, public welfare and the environment for sites with contamination remaining above unrestricted use levels after a Letter of Completion is issued for a site. The tools must facilitate monitoring, maintenance, and, if necessary, replacing engineering controls where they fail. Institutional controls cannot be the sole remedy if an acute exposure to any compound can exist.

2. Facilitates Safe Reuse of Sites. The appropriate application of LTS can and should facilitate the beneficial reuse and redevelopment of property at sites that have existing infrastructure and an available work force.
3. Reliable. Each stewardship tool should be evaluated for uncertainties and include contingency plans for addressing possible failures.
4. Transparent. Information on sites should be publicized and readily available, and the process should have an educational component so that public and private entities can readily participate.
5. Adequate Durability. The effectiveness of LTS tools must extend over the lifetime of the contamination risk. Given the potential duration of some remaining risks, current assumptions may require periodic reevaluation on a specific schedule and modification as needed. Stewardship should be incorporated into existing systems that already have a proven track record of durability, function and acceptance among likely customers. Examples include one-call utility notification systems (for example, 1-800-DIG-RITE), county property recording systems, and the title insurance industry.
6. Termination. Stewardship controls can and should be altered when risk levels change and terminated when controls are no longer needed to protect human health, public welfare and the environment.
7. Roles and Responsibilities. Stewardship management and implementation responsibilities must be clearly articulated, accepted by all appropriate parties, and documented through legal and/or other means. Responsibilities regarding the determination and apportionment of stewardship activities among government and private entities (including the site owner) must also be defined and stated at the outset. The parties responsible for enforcing stewardship requirements must be clearly identified and capable of taking appropriate actions.
8. Funding. The life-cycle costs of LTS must be assessed and incorporated into the remedial decision-making process prior to final remedy action decisions. Accurate cost estimates are critical to identifying the financial resources needed to ensure the long-term protection of human health, public welfare, and the environment. Any financial assurance instrument used must ensure that adequate funding is available to support the activities in the Risk Management Plan. At sites where comparable costs are incurred for remediating a site to unrestricted use levels and remediating a site to a lesser level plus the lifetime costs of LTS, the preference will be toward the former, as reflected in the National Contingency Plan [40 CFR 300.430(a)(iii)].
9. Application of New Science and Technology. Risk management plans should include a mechanism for periodic examination and re-evaluation of new technologies for remediation and stewardship tools over time. The objective of this re-evaluation would be to determine whether the application of new science or technology would provide a more cost-effective means of assuring or enhancing protection of human health, public welfare or the environment in on-going or future remedial actions.

11.3 ACTIVITY AND USE LIMITATIONS

If needed, AULs would be fully developed and proposed as part of the Risk Management Plan. AULs must be designed to ensure that site conditions that make the site safe for reuse remain. It is the job of AULs to guarantee that pathways of exposure to chemicals of concern (COCs) remain incomplete for as long as there are chemicals remaining that could pose an unacceptable risk to human health, public welfare or the environment. AULs must be readily accessible, durable, reliable, enforceable, and consistent with the risk posed by the COCs. AULs should also facilitate property transactions and redevelopment and beneficial reuse of Brownfields and other contaminated properties. A thorough discussion of AULs can be found in EPA documents (USEPA, September 2000 and USEPA, December 2002). The Risk Management Plan can use AULs or a combination of AULs from among the types identified below. The following instruments may be AULs and may be described in the Letter of Completion:

1. Environmental Covenants,
2. Engineered Controls,
3. Well Location and Construction Restrictions, and
4. Department-accepted ordinances adopted and administered by a unit of local government.

Environmental Covenants, Letters of Completion, and the recording requirements of the authority under which remediation is being performed apply to the property and must be transferred with the property (that is, run with the land).

11.3.1 Environmental Covenants

An Environmental Covenant is an AUL that is used to impose land use limitations or requirements needed to protect current or future users from environmental contamination. Covenants are subject to department approval as part of the Risk Management Plan. Activities or uses that may be limited or required include prohibition of use of groundwater for potable purposes, restriction to nonresidential property uses, prohibition of certain uses of the site such as the construction of basements or trenches, or the operation or maintenance of engineered controls. For MRBCA purposes, environmental covenants must be enforceable by the state.

A model covenant is attached as Appendix J-1. An environmental covenant contains the following elements:

1. Name of the property owners and declaration of property ownership,
2. Identification of the property to which the environmental covenant applies by common address, and legal description,
3. A reference to the Department of Natural Resources contact information for the program and authority under which the remediation was conducted,
4. A statement of the cleanup standards that were achieved in the site's cleanup,
5. A statement of the reason for the application of land use limitations and requirements relative to protecting human health, public welfare and the environment from soil, groundwater, and/or other environmental contamination,
6. The language instituting such land use limitations or requirements, and granting access to the department or its designee to inspect the condition of the property, the integrity of

controls, or other matters related to the contamination remaining onsite.

7. A statement that the conditions, limitations, restrictions or requirements apply to the current owners, occupants, and all heirs, successors, assigns, and lessees,
8. A statement that the limitations or requirements apply in perpetuity or until the department issues a new Letter of Completion approving modification or removal of the limitations or requirements, and a release or modification of the land use limitation is filed in the chain of title for the property that is the subject of the covenant,
9. Scaled site maps showing:
   - The legal boundary of the property to which the covenant applies,
   - The horizontal and vertical extent of chemicals of concern above applicable remediation objectives for soil and groundwater to which the covenant applies,
   - Global position system (GPS) data describing parts A and B,
   - Any physical features to which a covenant applies (e.g., engineered barriers, monitoring wells, caps),
   - The location of the source (if different from part A), and
   - The direction(s) of groundwater movement in subsurface zone(s) impacted by site-specific chemicals of concern,
10. A statement that any information regarding the remediation performed on the property for which the covenant is necessary may be viewed or obtained from the department. This information is maintained and available under the Missouri Sunshine Law (Chapter 610 RSMo.), and
11. The dated, notarized signatures of the property owners or authorized agent.

An approved environmental covenant must be recorded in the Office of the Recorder for the county in which the property that is the subject of the covenant is located. A copy of the recorded covenant that references the book and page of recording must be submitted to the department as part of the Risk Management Plan completion report, before the department will issue a Letter of Completion. The covenant does not become effective until it is officially recorded in the chain of title for the property.

A covenant remains in effect unless terminated in accordance with this guidance and applicable laws and regulations. The use of a site must be consistent with the terms of the environmental covenant imposed on the property unless the department approves a change in the terms of the covenant. In such case, documentation of the change shall be recorded in the chain of title and a copy of the materials recorded provided to the program under which the covenant was first imposed.

Deed restrictions may also serve as environmental covenants provided that they are enforceable by the state and run with the property. Private, or proprietary, deed restrictions and deed notices do not provide a durable assurance that limitations of uses for sites will be maintained and observed.

11.3.2 Ordinances and Supporting Memoranda of Agreement

An ordinance adopted by a local government can be used as land use control for risk-based corrective action purposes if it is supported by a memorandum of agreement between the local government and the department. This section describes these instruments.

Ordinances: An ordinance adopted by a unit of local government that effectively prohibits the installation and use of wells for potable or other purposes may be used as an AUL to ensure that the groundwater ingestion pathway is incomplete, as long as a memorandum of agreement, as described below, is in place. An ordinance may be used as an AUL if it prohibits the installation of water supply wells and requires the closure of any existing private wells, but does not expressly prohibit the installation of public potable water supply wells and require the closure of such wells owned and operated by units of local government.

Examples of two model ordinances are attached as Appendix J-2.

In a request for approval of a local ordinance as an AUL, the remediating party must submit the following to the department:

1. A copy of the ordinance restricting groundwater use, including prohibitions on new wells, certified by an official of the unit of local government in which the site is located that it is a true and accurate copy of the ordinance,
2. A scaled map(s) delineating the area and extent of groundwater contamination above the applicable remediation objectives including a summary of any measured data showing concentrations of chemicals of concern for which the applicable remediation objectives are exceeded,
3. Scaled map delineating the boundaries of all properties under which groundwater is located that exceeds the applicable groundwater remediation objectives, information identifying the current owner(s) of each property identified in the boundary map above,
4. Documentation that the current owners identified in 3. above have been notified that groundwater that extends beneath their property is the subject of a risk-based cleanup and that each has been sent a copy of this request as submitted to the department, and
5. Documentation that adjacent property owners have been notified of the intent to use the local ordinance as an AUL.

After approval by the department and issuance of the Letter of Completion, the remediating party must also notify, in writing, the unit of local government that an ordinance has been approved and used as an AUL. Written proof of this notification must be submitted to the department within 45 days from the date that the department's Letter of Completion is recorded. Appendix J-3 provides a model notification letter showing the contents of such a letter.

The department may void a Letter of Completion that is based on an ordinance if the local government revokes or repeals the ordinance or modifies the ordinance so that it no longer provides the protection that the Letter of Completion relied upon. Also, the Letter of Completion should state that it may be voided if the ordinance that eliminated the groundwater ingestion pathway is repealed or modified such it no longer provides that protection.

Memoranda of Agreement: Where an ordinance passed by a local unit of government is used as an AUL, the department cannot issue a Letter of Completion unless a Memorandum of Agreement (MOA) is in place. The MOA must include the following:

1. Identification of the authority of the unit of local government to enter into the MOA,
2. Identification of the legal boundaries, or equivalent, to which the ordinance is applicable,
3. A certified copy of the ordinance expressly prohibiting the installation of public and private potable water supply wells, the use of such wells, and the closure of existing wells,
4. A commitment by the unit of local government to notify the department of any variance requests or proposed ordinance changes at least 30 days prior to the date the local government is scheduled to take action on the request or proposed change,
5. A commitment by the unit of local government to maintain a list of all sites within the geographical unit of local government that have received Letters of Completion under the MRBCA process,
6. A provision that allows departmental access to information necessary to monitor adherence to requirements 4 and 5 above,
7. If applicable, the terms of any commitment by the local government to reimburse the department for periodic review of the local ordinance and actions relating to it, and for any actions taken by the department to address increased risks that arise from actions taken by the local government on the ordinance or related to it, and
8. The commitment of the local government to enforce the ordinance.

11.3.3 Engineered Controls

Engineered barriers may be used as AULs to prevent direct human or environmental exposure to contaminants, but controls to ensure long-term monitoring and maintenance must accompany their use.

An engineered control is a barrier designed or verified using engineering practices that limits exposure to or controls migration of the contaminants of concern. Access controls may be considered as an engineered control. Natural attenuation and point of use treatment are not engineered controls.

The use of engineered controls can be recognized in determining remediation objectives only if the engineered controls are intended for use as part of the final remediation.

Any Letter of Completion determination that is based, in whole or in part, upon the use of engineered controls requires effective inspection and maintenance of the engineered control. The inspection, maintenance and integrity certification requirements will be included in the Risk Management Plan. The Risk Management Plan should include contingencies to address temporary breaches of an engineered control. Absent such a provision, temporary breaches of the control, unless caused by Force Majeure, are prohibited unless approved by the department. Any breach caused by Force Majeure must be repaired in a timely manner.

11.3.4 Well Location and Construction Restrictions

State law (Chapter 256, RSMo) allows the Well Installation Board to adopt rules that limit wells or prescribe specific requirements for well construction. These can be used as AULs to the extent that they restrict access to certain groundwaters and thus limit the pathway for contaminants. Rules delineating special areas and setting out requirements for wells in those areas are contained in 10 CSR 23-3.100.

11.4 LETTERS OF COMPLETION ISSUANCE AND VOIDANCE

Issuance: A Letter of Completion is issued by the department after the satisfactory completion of the Risk Management Plan and after all applicable AULs are in place and their existence has been documented. Its issuance may be contingent upon the continued application of controls to manage activities. The letter attests to the successful completion of the Risk Management Plan and indicates the on-going activities (monitoring, property use restriction, etc.) that must be maintained.

The department will issue a Letter of Completion within 30 days of the department's approval of a Risk Management Plan completion report, which would include documentation of all filings of any covenants. This time frame may vary based on the implementing authority.

The department will mail the Letter of Completion to the remediating party and all property owners by certified mail, postmarked with a date stamp and with return receipt requested. The department may at any time correct errors in a Letter of Completion, or revoke it if AULs are no longer effective.

The department will include all of the following in a Letter of Completion. Depending on the authority handling the remediation, the generic completion letter may vary somewhat and may also include other site-specific information in addition to that outlined below. The letter may also include or be subject to administrative reporting, public participation, and long-term site review requirements of specific federal regulations under which authority a Risk Management Plan is completed.

1. An acknowledgement that the requirements of the Risk Management Plan were satisfied, including reference to the administrative record supporting completion of the site work,
2. The use level of remediation objectives (residential or non-residential use) specifying any AULs imposed as part of the remediation efforts; if the unit of local government has adopted an appropriate ordinance and entered into a MOA with the department,
3. A statement that the department's issuance of the Letter of Completion signifies a release from further responsibilities under applicable laws and regulations in implementing the approved Risk Management Plan and that the site does not present unacceptable risks to human health, public welfare and the environment based upon currently known information. If the remediation site is part of a larger parcel of property or if the remediating party decided to limit the cleanup to specific environmental conditions and related contaminants of concern, or both, the Letter of Completion should include this information,
4. The prohibition against the use of any remediation site in a manner inconsistent with any land use limitation imposed as a result of the remediation efforts without additional

appropriate remedial activities,

5. A description of any preventive, engineered or institutional controls or monitoring, including long-term monitoring of wells, required in the approved Risk Management Plan or a reference that specifies where in the Risk Management Plan this information can be found,
6. The obligation to record the Letter of Completion in the chain of title for the site,
7. Notification that further information regarding the remediation site can be obtained from the department through a request under the Missouri Sunshine Law (Chapter 610, RSMo.), and
8. A standard agency reservation of rights clause for previously unknown or changing site conditions. This wording will vary depending upon the authority overseeing the remediation,
9. Notification that the Letter of Completion may be voided for reasons listed in 11.4.2, and
10. A description of the remediation site by legal description, by reference to a plat showing the boundaries, or by other means sufficient to identify site location, any of which may be an attachment to the letter.

If only a portion of the site or only selected contaminants at a site were remediated, the Letter of Completion may contain any other provisions agreed to by the department and the remediating party, such as the limitation of the letter to the specific area or contaminants.

The remediating party receiving a Letter of Completion from the department must submit the letter, and, where the remediating party is not the sole owner of the remediation site, an owner certification described below, to the Office of the Recorder of the county in which the remediation site is located within 45 days after receipt of the letter. The Office of the Recorder will record the letter and, where applicable, the owner certification so that it forms a permanent part of the chain of title for the property. The remediating party is responsible for any cost of recording required by the county.

Where the remediating party is not the sole owner of the remediation site, the remediating party must obtain a certification by original signature of each owner, or the authorized agent of the owner(s), of the remediation site or any portion of the remediation site. The certification must be recorded along with the Letter of Completion. The certification must read as follows: "I hereby certify that I have reviewed the attached Letter of Completion, and that I accept the terms and conditions and will abide by any AULs set forth in the letter." The issuance of the letter is contingent on obtaining this certification from all owners.

A Letter of Completion is effective upon the date of the official recording of the letter and any associated owner certifications(s). Until it is in the chain of title, the Letter of Completion is effective only between the department and the remediating party. The remediating party must obtain and submit to the department an acknowledgement from the county recorder office that a copy of the letter and any owner certifications has been recorded. This acknowledgement must be provided to the department within 30 days after recording to demonstrate that the recording requirements have been satisfied.

No remediation site with AULs may be used in a manner inconsistent with any limitations unless further evaluation and/or remediation documents the attainment of objectives appropriate for the new land use. If the department approves modified AULs, then an updated Letter of Completion reflecting the new site conditions and requirements may be obtained and recorded as described above.

Voidance: The department may void the Letter of Completion if the remediation site activities are not managed in full compliance with the approved Risk Management Plan upon which the issuance of the Letter of Completion was based. The Risk Management Plan must also contain the specific details of any Long-Term Stewardship requirements that are relied upon to reach the conclusion. Specific acts or omissions that may result in voiding of the Letter of Completion include:

1. Failure to adhere to the terms of an environmental covenant,
2. Failure to adhere to any other applicable institutional controls, land use restrictions, or other AUL(s),
3. Failure of the owner, operator, remediating party, or any subsequent transferee to operate and maintain preventive or engineering controls, to comply with any monitoring plan, or any disturbance of the site contrary to the established AULs,
4. Disturbance or removal of contamination that has been left in place that is not in accordance with the Risk Management Plan. Disturbance of soil contamination may be allowed if, during and after any activity, human health, public welfare, and the environment are protected consistent with the Risk Management Plan or other health and safety requirements;
5. Failure to comply with the recording requirements or to complete them in a timely manner,
6. Obtaining the Letter of Completion by fraud or misrepresentation, and
7. Subsequent discovery of contaminants, releases, or other site specific conditions that were not identified as part of the investigative or remedial activities and which pose a threat to human health, public welfare or the environment.

If the department intends to void a Letter of Completion, it must provide notice to the current title holder of the remediation site and to the remediating party at his or her last known address, specifying the cause for the voiding and the facts in support of that cause. The department may give the remediating party a specified time to come into compliance with the terms of the letter. The remediating party or current title holder may appeal or seek dispute resolution on the department's final decision within 30 days after the receipt of the notice of voiding.

If the department voids a Letter of Completion, it may place a notice to that effect in the chain of title, pursue enforcement action, declare an environmental emergency, or take other action(s) to protect human health, public welfare or the environment, as appropriate.

11.5 INFORMATION AND TRACKING

Effective site information storage and timely retrieval are essential to redeveloping properties and managing site uses. A readily accessible and searchable repository of site information would allow developers to quickly judge the suitability of a particular parcel or group of parcels for a potential development, as well as assisting neighbors and the community in protecting their health and well being. To implement this information system, those using environmental covenants or ordinances as AULs should send that itemized information of Subsections 11.3.1 or 11.3.2, respectively, to the Director, Hazardous Waste Program.

This information will be maintained in an available and retrievable form. Commenters are asked to offer opinions on what should be the appropriate repository of this information. Possible repositories include governmental or nongovernmental entities. Governmental entities could include the Department (director's office, Hazardous Waste Program, Air and Land Protection Division, Geologic Survey and Resource Assessment Division) the Secretary of State's Office or other governmental offices (Department of Agriculture, Department of Economic Development, USEPA). Nongovernmental entities that provide the required services may also be suggested, as some already provide stewardship duties at some Brownfields sites. As this guidance is finalized, a decision will be made on the appropriate repository.

The department intends to identify and maintain information on sites in a number of ways with the objective of tracking information that will better serve the public and the redevelopment community. The department will maintain separate lists for 1) sites safe for reuse after cleanup, and 2) sites where contaminants were found but not fully assessed or remediated. Sites on the latter list may be candidates for listing on the existing State Registry of Confirmed Abandoned or Uncontrolled Hazardous Waste Disposal Sites. Please note that the UECA proposal would provide the opportunity to eventually eliminate the existing registry in favor of managing site information as prescribed in the UECA itself.

Cleanup criteria for a particular site are established at the time a Risk Management Plan is approved. As science progresses, additional characteristics of specific contaminants become known, and some regulatory cleanup criteria can be expected to change over time. Therefore, the department must maintain records on <u>all</u> sites remediated under the MRBCA process, including those cleaned up to unrestricted use levels and those with COCs above background levels. There may be cases where new scientific information indicates that unrestricted-use levels of COCs at a site are lower than the levels achieved at the time of cleanup, and this information should be available to those involved at that site.

Information about Environmental Covenants, Letters of Completion, and the recording requirements of the authority under which remediation is being performed must be maintained in department databases.

A Risk Management Plan encompasses all activities necessary to manage a site's risk to human health, public welfare and the environment so that acceptable risk levels are not exceeded under current or future land use conditions.

12.1 NEED FOR A RISK MANAGEMENT PLAN

A site-specific Risk Management Plan, approved by the department, is required at a site under any one of the following conditions:

- The total (sum of all pathways) carcinogenic risk for any COC exceeds 1×10^{-5},
- The Hazard Index (sum of all pathways) for any COC exceeds 1.0 (or, if appropriate, the Hazard Index for individual organ, system or mode of action),
- The cumulative site-wide carcinogenic risk (sum of COCs and all routes of exposure) exceeds 1×10^{-4},
- The site-wide Hazard Index (sum of COCs and all routes of exposure) for individual adverse health effect exceeds 1.0 (or, if appropriate, the Hazard Index for individual organ, system or mode of action),
- Although neither the carcinogenic or non-carcinogenic risk for any COC nor the site-wide risk exceeds acceptable levels, the risk assessment was based on site-specific assumptions that require a Risk Management Plan,
- Although neither the carcinogenic nor non-carcinogenic risk for any COC or site-wide risk exceeds acceptable levels, the groundwater plume is expanding, or
- Ecological risk does not meet the acceptable criteria.

The Risk Management Plan ensures that:

- Site conditions are protective of human health, public welfare and the environment based on achieving acceptable risk levels at any one of the three tiers discussed in Sections 8 through 10.
- Acceptable ecological protection is based on meeting any one of the three levels of ecological risk assessment (Section 6.11).
- Assumptions made in the estimation of risk and development of cleanup levels are not violated in the future, and
- The groundwater plume is stable or decreasing.

Successful implementation of the Risk Management Plan will result in a letter of completion from the department.

The following subsections provide general information on the preparation of the Risk Management Plan.

12.2 RISK MANAGEMENT PLAN

After it is determined that a Risk Management Plan is necessary for a site, the plan should include:

- Reasons why a Risk Management Plan is being prepared and the specific objectives of the plan. An example of a specific objective would be "remediation of soil to achieve specific risk-based concentrations for specific COCs."
- Dated reference to the approved Risk Assessment Report, particularly its discussion of pathways and receptors
- Application of technologies to reduce mass, concentration, and/or mobility of COCs to meet the cleanup levels determined for the site or specific engineering activities. Examples of technologies or remediation activities include soil excavation and off-site disposal, pump and treat, vapor extraction, enhanced in-situ attenuation, and monitored natural attenuation.
- Data that will be collected and quality control/quality assurance procedures for collection, documentation, analysis and reporting during the implementation of the Risk Management Plan. Examples of data that may be collected include confirmatory soil or groundwater sampling data to demonstrate the effectiveness of the remedial measures.
- Details of how and when data will be evaluated and presented to the department. Examples include trend maps, concentration contours, concentration vs. distance plots, calculations related to mass removal rates, or application of specific statistical techniques.
- Application of activity and use limitations (AULs) to eliminate certain pathways of exposure and ensure that the pathways remain incomplete under current and future uses. Examples include conditions imposed on the property that prevent the installation of wells, thus eliminating the groundwater future use pathway, or prohibition of future residential land use.
- If needed, monitoring to demonstrate plume stability or the effectiveness of natural attenuation.
- A long-term stewardship plan that ensures that the AULs are effective and maintained, that site conditions do not change to result in unacceptable risk, and that site information remains available to interested parties.
- A schedule for implementation of the plan. If the duration of the planned activities exceeds a few months, a detailed project time line must be developed. It must include all major milestones and all deliverables to the department.
- Criteria that will be used to demonstrate that the Risk Management Plan has been successfully completed.
- As appropriate, contingency plans if the selected remedy fails to meet the objectives of the Risk Management Plan in a timely manner.

The department will approve the Risk Management Plan as submitted or provide comments. If comments are made, the department will work with the Remediating Party to revise the Risk Management Plan and to resubmit it for approval. Upon receipt of approval, the remediating party should begin implementing the plan.

However, as noted earlier in this guidance, both RCRA and CERCLA operate under specific public notification, review, comment and response requirements that must be met before those authorities can make a final decision to approve a Risk Management Plan.

12.3 COMPLETION OF RISK MANAGEMENT ACTIVITIES

Upon successful completion of the approved Risk Management Plan, the remediating party must submit a Completion of the Risk Management Plan Report to the department for approval that includes:

1. Documentation of completion of all risk management activities, and
2. If applicable, a request to plug and abandon all nonessential monitoring wells related to the environmental activities at the site.

Again, both RCRA and CERCLA may require interim or additional reports once the final remedy is operational but before remediation performance standards have been met.

12.4 PROCEDURE FOR LETTER OF COMPLETION

After the Risk Management Plan has been successfully implemented, the remediating party may request a Letter of Completion from the department**.** The department will issue a letter if the site satisfies all requirements of the approved Risk Management Plan. The letter would state that, based on the information submitted, the concentrations of COCs on or adjacent to the site do not pose an unacceptable level of risk to human health, public welfare and the environment for the current and future land use and provided that all AULs remain in place. Section 11 contains more detailed guidance on the Letter of Completion.